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EUROPEAN TECHNOLOGY & INNOVATION PLATFORM

The European PV Manufacturing Industry: Analysis and Policy Guidance for 2020 and Beyond

Edition I

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Layout and Printing

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Disclaimer

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Introduction

This document is ‘Edition 1’ of “The European PV manufacturing Industry: analysis and policy guidance for 2020 and beyond”. It is Deliverable D2.11 of the FP7 contract PV TP- SEC III.

Evidence base

Interviews

The evidence base for this report is the statements made by a number of experts from Europe’s PV manufacturing industry interviewed between September 2014 and June 2016. Most sections of the manufacturing chain in Europe were covered.

The steering group of this report (known internally to ETIP-PV as the “Ad hoc Working Group on Industry Policy and Strategy” and referred to in this report as the report’s steering group) approached contacts of theirs in the manufacturing industry and helped to set up interviews with Greg Arrowsmith (EUREC), this report’s writer principal writer, who conducted the interviews, sometimes supported by a steering group member. The interviews took roughly one hour. An outline of the topics that would be covered was circulated in advance.

Representatives of the sectors below were interviewed:

- 4 polysilicon producers (two established, European; two start-up)
- 6 equipment providers
- 5 inverter manufacturers with operations in Europe
- 3 thin-film PV manufacturers with operations in Europe, or who used to operate in Europe
- 4 crystalline silicon PV manufacturers with operations in Europe, or who used to operate in Europe
- 2 manufacturers of III/V CPV cells and/or modules with operations in Europe, or who used to operate in Europe
- 1 manufacturer of BIPV products

Written responses to questionnaires

Sometimes an expert provided written input instead of being interviewed:

- 1 material provider
- 2 thin-film manufacturers
- 1 module manufacturer
- 1 developer

Literature

A number of academic papers, non-academic reports and press cuttings have been written on the state of the EU’s manufacturing industry. Speeches have been made in public fora. Evidence from these sources has been taken into consideration, too. Many of the sources were suggested by the steering group.

Oversight

Steering group

The steering group, which met in different configurations to discuss progress on the interviews and report, consisted of

- A Roesch
- C. del Canizo
- W. Sinke
- P. Malbranche
- B. Dimmler
- E. Perezagua
- A. Virtuani
- E. Olsen
- J. Silva
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- S. E. Foss
- S. Tselepis
- P. Mints
- R. Ordas
- P. Wohlfart
- F. Roca
- A. Bett

Meetings were held in September 2014 at EU PVSEC, in September 2015 at EUPVSEC and in June 2016, also at EUPVSEC. Progress was reported in the interim to the Steering Committee of ETIP-PV.

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- R. Schlatmann
- F. Ferrazza
- G. di Franco
- M. Raganella
- J.-P. Joly
- A. Serafini

Anonymity policy

The experts who were interviewed do not wish comments they made in interview to be attributed to them. Statements made in open meetings where press was or could have been present are however attributed to the speaker.

Further work

A Second Edition of this report is foreseen containing additional sections and, guided by the steering group, conclusions.

Among the additional sections for the Second Edition will be:

- Scale as a source of competitive advantage
- Vertical integration as a source of competitive advantage
- Patient capital, slow expansion and exposure to non-PV sectors as survival strategies
- A future based on niches?
- Snapshots of the confidence of different industry leaders in their future

How did China secure its position as a major PV manufacturer?

PV manufacturing was **pushed forcefully from the top down by the Chinese government**.

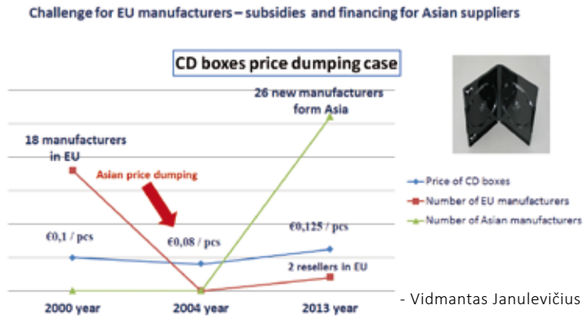
Credit to China for realising early how important sector this would be. Contributor A (developer) says, “China decided to take over the PV Industry.” Contributor Z says China started its takeover of PV in 2007 with “one specific decision by the Chinese prime minister to invest hundreds of billions of dollars in this field.” Interviewee B (crystalline silicon PV manufacturer) says that by 2008 and 2009 the shift was underway, “The government of China decided that PV industry and dominance in it is of strategic importance.” Interviewee C (III/V module manufacturer) spoke of the government taking a “strategic” and a “political” decision.

China’s interest in the technology was welcomed by Eicke Weber, boss of the research centre Fraunhofer-ISE, who has spoken of a benign ‘German-Chinese conspiracy’ to give the world clean and cost-effective PV, with “Germany providing the market, and China the investment capital”[1]. The association of “feed-in tariffs in Germany and the massive subsidies for manufacturing (i.e. upstream) in China” was “improbable” said Interviewee D (crystalline silicon PV manufacturer), but it happened. “The Chinese raced to decrease price to increase market share.” Interviewee E (thin-film PV manufacturer) recognises that this “globalisation” of the industry achieved its purpose of giving the world low-cost modules.

China, especially, has attracted criticism for the manner of its takeover (explored in the next chapter). It used an approach that it has used in many other sectors in the past. BOD Group CEO, Vidmantas Janulevičius, speaking at the June 2014 General Assembly of the EU PV TP[2] , had an example: CD jewel cases (Box 1).

Box 1 - **An example outside PV of an attempt by Asian companies to dominate a sector: CD jewel cases**

“In 2000, there were 18 manufacturers [of CD jewels cases] in the EU. At that time the price was roughly around 0.10 €/case. In 2004, Asian companies come onto the market and used dumping prices. Prices dropped to 0.08 €. Because it was not possible for European manufacturers to produce at this price, roughly 16 went insolvent. In one year, all their equipment was bought at one tenth the price they paid for it, by the Asian producers. That means that in 2013, we have 26 new manufacturers from different countries in Asia. The price returned to 0.125 €. 4 800 jobs in Europe have been lost, with a social security cost that Europe has paid. Europe now buys mostly from Asia. The quality is really bad [...]. We are really not afraid of real competition, but I would like not to see cheap money being used in this way”.



- Vidmantas Janulevičius

[1] His wording in his address in the Opening Session of EUPVSEC 2015 (14 September 2015). He made similar statements albeit omitting “conspiracy” at various events since. The “billions” of investment in large scale production lines in China and other Asian countries came from foreign direct investment and money already in the countries said *this report* (dated 22 April 2016) by Fraunhofer ISE.

[2] Minutes of General Assembly June 2014

China (and other Far-Eastern countries) are **low-cost.**

Labour is cheaper in the Far East, say the majority of interviewees, and this fact boosts that region's competitiveness as a manufacturing centre. Contributor Z said the labour cost advantage would persist "for the next 20 years, but not the next 40 years."

Interviewee F (crystalline silicon PV manufacturer) said, "Salaries are an important factor. There is no difference between Malaysia and China, but there is a difference between Malaysia and Germany or Poland, one that is important in an industry where you're fighting for every dollar." If Poland counts as 'Eastern Europe', then Interviewee B disagrees: "Labour cost [in China] is like in East Europe."

Interviewee G found that while labour costs were "not so important" a consideration in the choice to site his company's 300 MW thin-film line in the China (given that it would be "almost fully automated") other sources of cost-saving still had a big enough impact to swing it: "Actually it makes a difference to be in a low-cost country. It had impact on many places: electricity, space, buildings, the basic materials, transportation. Even if you are fully automated I don't believe this is enough for a high-cost country in Europe to compete." Interviewee E (representing another thin-film manufacturer) agreed that in going towards more automation, like his company also is, labour costs decline in importance. And IHS Technology, reports Photon International [*PHOTON 2016*][3], has declared labour costs not to be significant, ultimately, in determining the competitiveness.

Chinese companies took an **early interest in cost engineering**

Interviewee D praised the leanness of Chinese manufacturing: "They have trimmed their costs. […] They have excellence in optimising industrial process, cutting cost on all the elements: steel, glass, utilities, everything where they benefit from the fact that steel is cheaper, glass is cheaper, a lot of elements are cheaper." D says the prices for these materials in the Far-Eastern countries where his company manufactures, Malaysia and Philippines, "is not much different".

Inverters have been a battleground for lean manufacturing, too. Photon International carried a story in 2010[4] showing an inverter made by a Korean company, Dasstech, led the way in keeping down manufacturing cost. Its inverter had "material costs per Watt-peak less than half of SMA's". SMA was in 2010, and still is, Europe's leading inverter manufacturer. SMA went on to "encounter considerable problems as a result of competition from Asia," wrote Photon International, "Years later, it admitted to problems resulting from high component costs and started to take measures to reduce them. And those may have happened just in time."

Looking back today on the attitudes of big European manufacturers 5-10 years ago, few have kind words to say. "They got lazy," said Interviewee I (III/V module manufacturer), who has been in the industry for 30 years. Companies were in an artificial market that they thought would continue. A similar feeling was to be found in people who'd moved into the industry at the time of the European PV boom. Interviewee F joined the PV industry in 2008 from the microelectronics sector: "My impression of 2006 was the world was really too much rosy for companies because they sometimes did not manufacture efficiently. They didn't feel the pressure

[3] Photon International, June 2016, 'The big players lead the race' p42, quoting this *April 2016 study by IHS Technology*

[4] Recalled in its "20 years of Photon" edition, March 2016, page 23

How did China secure its position as a major PV manufacturer?

of how you should organise manufacturing very well because prices were so good. They all made a lot of profit."

They had various opportunities to get their house in order, says Interviewee J (Equipment provider), but they missed them all. Their last chance came in 2009-10. J remembers pleading to Solarworld and Q-cells, "It's not the cheap money in China that will give you headaches. It's not that you are premium and they are stupid and making lousy products. Start to benchmark, like the automotive sector. Try to network with a Chinese manufacturer. Compare your cost structures. Then you will see you need to do homework. You buy too expensive silicon. You have to get rid of those stupid contracts if possible. Your consumables are minimum 50% more expensive coming from the same companies as the Chinese. Your sometimes ignorant engineers are putting overspecifications to equipment vendors. You never buy standard equipment, so you pay at least 20-30% more in investment, without benefit. I offered to help. I will invite Chinese, I said, we will do this at my company. But they ignored me, telling me, 'We don't want to disclose our premium technology to them.' I said, you don't have premium technology any more. This moment, in 2009-2010 was their last chance." In 2011-12 the storm hit.

Solarworld maintains it did benchmark its costs, but did so without Chinese involvement, and maybe Interviewee J warnings were heeded in Q-cells. An interviewee from that company said that 2009-2011 he saw people join Q-cells from a mature industry, "improving manufacturing with their knowledge. Now the standard of manufacturing in the PV industry has reached the standards of mature industries. There was a lot of improvement in organisation, in how to run a production [line]."

As for SMA, Interviewee K remembered the Photon International article. In 2012 SMA bought a majority stake in Zeversolar, a Chinese manufacturer. This enabled SMA to "combine the best of two worlds: Chinese efficiency and German quality standards", as Zeversolar's homepage says[5]. Engineers from China and from Germany learned from each other, said Interviewee K. By 1 Jan 2015, SMA had increased its shareholding to 99.34%, but in the same year, after "two years of double-digit losses (Editor's note: losses were in fact 164 M € in 2014[6]), the company made 1 500 employees redundant." At about the time as [*PHOTON 2016*] was hitting the shelves, SMA's CEO, Pierre-Pascal Urbon was being quoted in his company's Annual Report 2015: "At the start of [2015], nearly no-one expected sales of around €1 billion, a positive net annual income and even a dividend."

China **"hired clever people from all over the world"**

Those words were Interviewee J's. The eminent PV researcher Martin Green from UNSW agrees. In an article for PV Magazine of June 2016[7], he quotes research from China that recognises the leadership roles taken by several former members of his department in the early days of China's PV industry. Contributor Z recalled the career path of Shawn Qu, who cut his teeth at a European manufacturer before going on to found Canadian Solar, a major manufacturer in China. He was given the equipment to launch his company in return for equity.

In 2010, *Mines Paristech* reported that Chinese companies were actively scouting for "middle-level management employees." Indeed, "the recruitment of skilled executives from the Chinese diaspora" was one of two "main" ways "that Chinese producers have acquired the technologies and skills necessary to produce PV products." (The other was by "purchasing of manufacturing equipment in a competitive international market.")

[5] *https://www.zeversolar.com/*

[6] *2015 Annual Report*, for example p58

[7] Revisiting the History Books, p96

But mobility within the industry brings with it a number of challenges, particularly with regard to the protection of intellectual property and maintaining high quality standards.

VDMA/Impuls 2012 warns its members (Germany-headquartered equipment manufacturers) that there exists "a danger that Chinese colleagues fired during the downturn in PV manufacturing in China, will go and work for local producers!"[8] *Mines Paristech* confirmed the existence of knowledge diffusion: "The local mobility of Chinese employees has also accelerated knowledge diffusion within China." So, says Interviewee F, "If you want IP [protection] for your product you'll limit transfer of know-how to China because once the know-how is in your sister company in China, then these people are talking to each other and the people who are now in your company next will be in a different company. […]. I would see this as the most critical point for production in China." Another company interviewed (equipment provider) has the same policy, and for the same reason.

Chinese equipment manufacturers, like their Europe-headquartered counterparts, recorded slumps in orders and limited access to capital, *VDMA/Impuls 2012* said. One effect of this, said *Mines Paristech*, was that the representatives of Chinese companies interviewed for that study "complained during our interviews about their employees being hired by other companies or creating their own company. […] There even exist agreements between the 9 biggest Chinese solar firms to prevent hiring each other's skilled employees."

The skill of workers on the factory floor has a direct impact on the quality of the finished product. "You need to have trained people to run a line. High turnover of people is a problem," said Interviewee L (polysilicon producer). Interviewee M (equipment producer) said that annual turnover reaches 50% in China. "You can't train all those people in ISO 9001 regulations [Editor's note: a quality control norm]. It's not possible. For the Chinese, ISO 9001 is just a paper." Enforcement is stricter in Europe, and staff churn might also be less there. Interviewee N (polysilicon producer) reported low staff turnover at his company. Interviewee O, a Norwegian polysilicon producer, said "Norwegians are very conservative in the job movements." It has been difficult to coax them back to the PV industry after they dispersed during the European rout.

Chinese companies can bulk-buy **raw materials**.

[*PHOTON 2016*] said "30% of the cost advantage [of Chinese Tier 1 companies] is due to much cheaper material procurement." An older study by *MIT-NREL* (July 2013)[9] indicated that, in the authors' view, "China-based factories enjoy a 10% purchasing leverage deriving from increased customer scale (2,000 MW/year vs. 500 MW/year) [and] additional regional price discounts ranging from 5% to 15% for specific materials used in PV manufacture."

The 2015 Annual Report of SMA says its executives "are pooling synergies at an international level, not just resources for purchasing, but also when it comes to production and development, such as between SMA and its subsidiary Zeversolar," which is in China. SMA has the largest market share of all inverter manufacturers, at 14%[10], giving it the greatest possibility to make savings from bulk purchasing.

It is possible to capture some economies of scale without being a Giga-producer of PV. Interviewee F, who works for a conglomerate in which PV is only one business unit areas among many, says, "We have global purchasing. We try to address our suppliers saying we are purchasing for the whole PV group, even whole conglomerate, so that small manufacturing units get the benefits of the larger group."

[8] Slide 16 – presentation from May 2013: *http://leibniz-institut.de/Konferenzen/ee2013/wessendorf_photovoltaik-maschinenbau_made_in_germany.pdf*

[9] See Electronic Supplementary Information for the study, *http://www.rsc.org/suppdata/ee/c3/c3ee40701b/c3ee40701b.pdf* , Table 3

[10] May 2016 article here: *http://www.pv-magazine.com/news/details/beitrag/sma-clings-to-global-inverter-top-spot--but-chinese-rivals-closing--says-ihs_100024574/*

Chinese subsidies and dumping

Many interviewees resent the way China seized market share. It was done through "massive credit lines at zero interest and export subsidies from the Government," said Contributor A (not quite zero, recalls one of the report's Steering Group from a conversation with REC, 2%, but that was still a lot less than the 7% general bond rate at that time).

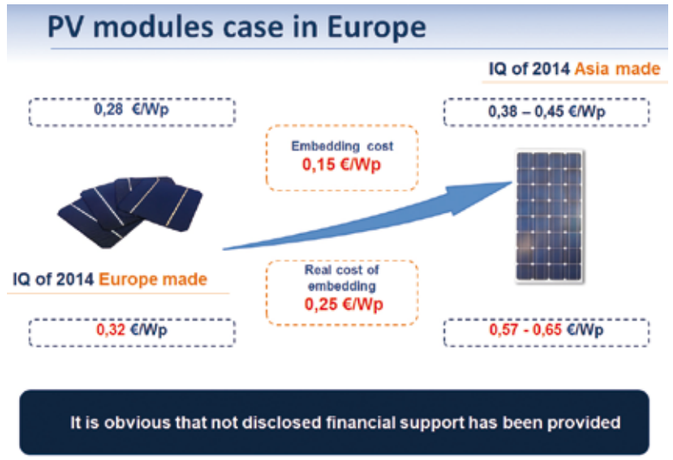
Interviewee C said, "The different financing rules in China of all these activities of the RoW was not really an equal competition" and moved manufacturing to China faster than expected. "If you look at the list of benefits, numbers 1, 2 and 3 are 'Financing, financing and financing'. This made a huge difference. Access to cheap money. That was the main difference."

Interviewee J, on the other hand, is more inclined to think of cheap finance as one factor among many, and that the unwillingness by European firms to keep costs down (see later) played a far bigger role.

A number of interviewees besides Interviewee F mention subsidies paid or provided in kind by the Chinese government, never in favourable terms, for example Interviewee P (equipment provider): "If you take a look at the past balance sheets of the public companies in China and you really know the cost of PV, then you know that the Chinese companies are continuously losing money, so it is a competition that is I think not fair – worldwide to have a government-funded manufacturing that the government keeps alive with lots of money."

Some put a figure on the scale of the support. A speaker at the SOPHIA symposium (Jan 2015 in Chambéry) said, "We cannot compete with the Chinese companies which get every 5 years $10 bn! Trina, JA Solar, Yingli… This is now the second time!" And then, for humour, "Give me only 3 bn!" Speaking later, in an interview, he said a fourth company was among those that had benefited from government support, and that he derived the $10 bn figure from the dumping margin. In 2016 Chinese financial regulators called on the country's development bank to bail out Yingli with €1 bn[11].

BOD Group made a similar calculation. Its CEO Vidmantas Janulevičius presented the slide below at the June 2014 General Assembly of the EU PV TP[12].



Caption: Some Asian producers offer modules at 38-45 cEUR/Wp. Cells, on the other hand, are offered at 28 cEUR/ Wp, which is more or less the real cost. Having been put out of business in Europe, the fact that they are sold at real cost is to be expected. The implied embedding cost of 15 cEUR/ Wp (i.e. the cost of the transformation from cells into modules) is impossibly low. BOD Group achieves 25 cEUR / Wp allowing for some margin. It makes cells costing 32 cEUR/ Wp (profitably) and needs to price modules at 57-65 cEUR / Wp to make a profit. Vertical integration might give Asian producers a cost advantage of 10%. The rest of the difference is made up with hidden forms of financing. Anti-dumping measures are justified, says BOD.

[11] *http://www.bloomberg.com/news/articles/2016-04-08/china-said-to-push-for-1-16-billion-in-loans-for-yingli-imri0khz*. The source for the story is not named.

[12] Minutes of General Assembly June 2014. Fix broken links on ETIP-PV website.

There are statements by Chinese manufacturers on the record about the amounts and forms of subsidies they received.

[*USA-Manuf 2012*[13]] found evidence for below-cost selling: "[China's 12th Solar Five-Year Plan] states a goal of reducing the cost of PV modules to 7,000 yuan per kW ($1,100 per kW or $1.10 per watt) by 2015. However, current pricing of Chinese PV modules is already significantly below this target, indicating sales below cost."

Interviewee Q (equipment provider) said, "The whole supply chain in China is very much supported by the government and in Europe there is hardly any support for PV manufacturing. […] if China keeps on pushing and supporting its industry and Europe or America holds back from doing so, the future is that indeed the Chinese manufacturers will dominate."

It may be true that China's direct support for PV manufacturing far outweighs Europe's (A Table from [*JRC 2015* Table 6, p24, quoting 2013 data] shows that Inner Mongolia Autonomous Region made available $1.2 bn to manufacturers), but Europe did also have some money available. Interviewee F gave anecdotal evidence of local government subsidy in the Netherlands to build a plant. BOD Group got 17 M € from the EU on total investment costs of 44 M € for a building that houses its PV business[14]. Subsidies were paid to a number of German manufacturers in mid-2000s (Box 2). But in 2015 [*HLG-KET 2015*] felt the EU could do more to facilitate regional funding: "Some WTO rules on subsidies and countervailing measures [were] phased out in the year 2000. This change motivated other regions to implement attractive investment aid. Only the EU kept strict regional aid provisions."

Box 2 – **Direct public subsidy to PV manufacturing in Germany**[15]

A non-exhaustive search reveals the following handouts to manufacturers:

All amounts in M €	2004	2007	2009	2010	TOTAL public subsidy
Q-cells	22.4	41.4	56 (to daughter Sunfilms)	17 (to daughter Solibro, and further direct funding from Federal and State level)	
Solarworld					137.3 in three installments
Conergy					76
Bosch					55

A Q-cells daughter, Sovello, had to pay back 11 M EUR of EU regional funding in 2010 because of misclassifying itself as an SME.

Solarworld is described as "hanging in the game" by Interviewee I. They stayed alive by spending a lot of money. It has 500 M EUR of debt and picked up Bosch's assets for free, he alleges.

Solarworld's period of subsidisation is now behind it, maintains a representative of the company who spoke to the EU PV TP Steering Committee in Sept 2015: "We are a European not state-financed/state-subsidised company. We went through a brutal financial restructuring in 2013-14. All our competitors either exited the market, shut up factories went bankrupt or whatever, especially in Germany." The subsidies that Solarworld received were open to any company investing in the economically disadvantaged region of Eastern Germany.

[13] Published 2 May 2012

[14] http://bod.lt/pl/about-us/news/1412/ and slide 7 of his General Assembly 2014 presentation

[15] Sources: press articles from 2010-2012 http://www.manager-magazin.de/unternehmen/energie/a-785680-2.html, http://www.manager-magazin.de/unternehmen/energie/a-785680.html, http://www.manager-magazin.de/unternehmen/energie/a-825330-2.html, http://www.it-times.de/news/q-cells-beteiligung-sovello-muss-foerdergelder-zurueckzahlen-20269/

What should be Europe's response to China's distortion of the PV market?

Europe's response, since 5 December 2013, has been to put in place "anti-dumping" and "anti-subsidy" duties on cells and modules from China. Since February 2016, producers from Taiwan and Malaysia found by the European Commission to be allowing Chinese product to transit through them as a way of circumventing the anti-dumping and-subsidy measures also face duties. The Chinese manufacturers are exempt from the duties if they sell in the European Union at a price above a determined Minimum Import Price[16]. Updated dumping margins for solar cells being sold in the US were recently published, putting them at between 6 and 12%[17].

This response can be challenged on different grounds.

1. At one extreme, the case may be made that trade in PV products should be completely free and that the only concern is the cost of PV products to the end-buyer. This is the position of SAFE, which carries this notice on its website[18]: "The continual expansion of photovoltaics [is required] at the most affordable cost. Trade restrictions for solar products – such as minimum prices or punitive tariffs – stand in the way of this development. It is for that reason that we reject these and campaign for their abolition."
2. Another position is to not rule out trade barriers, but to take positions case-by-case. Solar Power Europe has twice written to the European Commission specifically on "the trade case on the import of solar cells and modules from China"[19]. But wording in its more recent letter suggests it is erring towards a blanket rejection: "Trade measures will not lead to improved economies of scale in European module production." In 2015, however, the association had preferred to hedge its bets, calling for "free and fair" trade[20]. These are two notions that can come into conflict.
3. Alternatively, one can be against the forms of trade barrier Europe has opted for, but in favour of other forms. Interviewee C and Interviewee S (equipment provider), for example, are afraid that anti-dumping penalties will attract retaliation from China, but much more supportive of so-called 'local content rules'.
4. And finally, at the opposite extreme to SAFE and Solar Power Europe, one can be in favour of the measures as they currently stand, or of tightening them or complementing with others (Box 3). This is the position of the association EU ProSun.

Box 3- **Some have spoken on-the-record of the need to maintain and enforce EU anti-dumping measures**

- Vidmantas Janulevičius (EU PV TP General Assembly June 2014): "Strict actions for anti-dumping required!"
- Speaker at SOPHIA Symposium Jan 2015: "Europe just needs to make sure the rules we have decided to set up are respected. If there is a MIP agreement signed between Europe and Chinese authorities, can Europe control that it is being upheld? […] Europe has to force the rules to be respected. Customs is controlled by Europe."
- Milan Nitzschke (April 2016): "The Chinese overcapacities are being financed by the state. That is exactly the reason why the EU has imposed anti-dumping measures and must continue with those"[21]

[16] EC factsheet Feb 2016: http://trade.ec.europa.eu/doclib/docs/2015/july/tradoc_153587.pdf

[17] Federal Register 20 June 2016, https://www.federalregister.gov/articles/2016/06/20/2016-14532/crystalline-silicon-photovoltaic-cells-whether-or-not-assembled-into-modules-from-the-peoples

[18] http://safe-eu.org/about-safe/?lang=en

[19] 18 Sept 2015, 4 July 2016

[20] Press release 27 April 2015

[21] http://www.rechargenews.com/solar/1430056/study-of-european-pv-prices-rekindles-debate-on-china-duties

Surveys reported in literature

"Most" of the "20 top global solar executives" who participated in a workshop at Stanford University[22] in summer 2013 "said the solar industry already has become so global that most countries have more to lose than to gain by such tariffs." But those interviewed for *a 2014 study* for DG Enterprise were divided: "There are mixed opinions as to whether the European anti-dumping policy measure on module prices is detrimental to the solar PV industry. European module manufacturers welcome the tariffs; conversely project developers see the policy as a barrier to more cost-effective deployment." Among those interviewed for this present report, who were, to recall, "manufacturers" and not "project developers", the most common position was to support "fair" trade in the products they make, in line with the DG Enterprise study's experience.

Arguments against anti-dumping

It can be circumvented financially or by shipping. "Up to 30% of Chinese solar imports bypass EU import measures through fraudulent circumvention," Nitzschke has said[23]. Considering the US, which introduced tariffs equal to a percentage of the price of products arriving at its border, Contributor X says, "If tariffs were effective [at protecting US manufacturers], we would not today (Oct 2016) be seeing prices as low as 0.38 $/Wp."

Financial circumvention is through a system of "refunds". Interviewee T (crystalline silicon PV manufacturer) pointed to this as well as a Steering Group member: "Controls at customs are often ineffective," said Interviewee T, "The price declared at customs on imports from China of 0.53 €/W p [Editor's note: the MIP at the time of speaking, since raised to 0.56 €/W p[24]] is then lowered on the market." The ways the lowering happens are by repaying a commission to the buyer, said Contributor Z: "You may know that some project developers are buying modules from Asia at a price written on the invoice equal to the MIP and receive commission to reduce this price to the international market price (of 0.45 $/W p). Even the Chinese government is struggling to prevent its own companies from doing that." Interviewee K reported a trick involving combined inverter-module shipping: "There's never been any anti-dumping measure on inverters. One time an installer gave me a movie that he recorded of a Chinese representative who foolishly told him – listen what I'm going to do is highly illegal, but if you want to buy it at MIP price I'll give you free inverters in a combined package."

Then there's circumvention by 'transhipment', which the European Commission recently clamped down on. Here a Chinese manufacturer sends product to Europe via a country not caught by anti-dumping. The European Commission concluded that its "measures against solar modules and cells of Chinese origin were being avoided by means of transhipment via Taiwan and Malaysia"[25] and moved to close the loophole in February 2016. Interviewee B alleges that "If a company from China moves to Malaysia, to any country in southeast Asia, they still get support from China."

Several point out that European manufacturers do not appear to be benefitting from the anti-dumping and anti-subsidy measures. Interviewee F took an example from another area, anti-dumping on glass. "If we buy glass from China, we pay 40% tax on glass for our production in Europe. Works out at several euro per module – significant. If I have a factory in Malaysia, I do not pay these taxes [Editor's note: because not covered by anti-dumping measures] and I can export my product to Europe. European glass makers do not benefit from this arrangement because of the opportunity […] to circumvent. European module manufacturers don't benefit, either. […] All approaches I know like taxes can be circumvented by global companies."

[22] *http://law.stanford.edu/wp-content/uploads/sites/default/files/publication/443568/doc/slspublic/2013-10-31%20Final%20solar%20report.pdf*

[23] *https://drive.google.com/file/d/0B3Ux9yzCG1hva0YtWElZbUdTdXc/view?usp=sharing*

[24] *http://www.pv-magazine.com/news/details/beitrag/eu-to-raise-minimum-import-price-for-chinese-solar-modules-_100018620/#axzz4CIX0DVse*

[25] *http://trade.ec.europa.eu/doclib/press/index.cfm?id=1461*

What should be Europe's response to China's distortion of the PV market?

Neither Solar Power Europe nor John Smirnow — vice president of trade and competitiveness for the Washington-based Solar Energy Industries Association (SEIA) – see how anti-dumping measures could lead to a manufacturing revival in the countries or regions that introduce them. Solar Power Europe says, "the measures […] benefit no-one in Europe – not even the module producers they were designed to protect."[26] Smirnow reportedly said[27] that US duties on Chinese solar products have mainly benefited "third countries" such as South Korea, Malaysia and Thailand, rather than Solarworld USA [Editor's note: Solarworld USA is the largest manufacturer in the country].

This is questioned by two interviewees. Interviewee P spoke of "rumours in the market that manufacturing might return to Europe partially due to anti-dumping," before qualifying his statement: "We will see. I don't know. I would be very happy if that happened."[28] He remembered a slide put up during a DG Energy event, "EU: Leading Global Technology and Innovation in the Renewable Sector"[29] indicating that manufacturing was becoming more dispersed, but not claiming that Europe benefitted the dispersal. It contained the line "China and Taiwan face serious impacts due to anti-dumping. Several players are looking for outside manufacturing: CSI, TRINA, Solartron[30], NSP." Interviewee J identified the same trend and cause: "Some of the Chinese manufacturers are leaving China because of the import duties." One has since invested in Europe apparently to dodge the EU's and US's tariffs. Trina bought a 200 MW cell line in the Netherlands to "further expand [its] presence and enhance [its] competitive edge in overseas markets, especially the U.S. and Europe" [31]. This announcement came weeks after Trina exited the MIP Undertaking[32], lending credibility to the idea that it did so because it could serve the EU market (and the US market) from its new plant[33]. Aleo Sunrise GmbH was more explicit in the press statement announcing its plan for 200 MW of new cell manufacturing in Germany: One of the purposes, said the CEO, was to "protect ourselves against anti-dumping duties."[34]

The anti-dumping measures might have been effective (or more effective) in protecting the EU cell and module manufacturing industry if they had followed the US model. A Solarworld representative told the September 2015 Steering Committee meeting of the ETIP-PV, "I think the best example today is the US. The US implemented measures to achieve [a] level playing-field. You today have much higher competition in the US market, a much higher variety of solar products, decreasing prices, and we have a global market." The crucial difference was timing, said a steering group member[35]: "Anti-dumping measures arrived at the moment that the American market started, so it was at the right time." Interviewee T, who had planned to set up manufacturing in Europe (plans since postponed indefinitely), said[36], "Reaction to unfair dumping practices from Asia at European level too slow and with little courage: Actual cap of 7GW/y to imports of PV from China is too high and enough to saturate the (2014) European market." Another manufacturer (thin-film) found the competition from Asian manufacturers unfair, and that the European authorities were slow to react to it. Vidmantas Janulevičius twice said the same, speaking at the June 2014 ETIP-PV General Assembly. So did Interviewee E.

Anti-dumping rules are not popular with interviewees D, F, I, N or S.

[26] 4 July 2016 letter to Commissioner Malmström

[27] RECHARGE NEWS article 27 April 2015

[28] Interview … Aug 2015

[29] 19 Jan 2015 in Abu Dhabi

[30] See, for example, this press report: *http://www.pv-tech.org/news/thai_module_manufacturer_solartron_to_double_production*

[31] Trina press release 23 Feb 2016

[32] *http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL%3A2016%3A023%3AFULL*

[33] This is what two articles conclude: *http://www.pv-magazine.com/news/details/beitrag/trina-solar-acquires-200-mw-dutch-solar-cell-factory-from-solland-solar_100023334/#axzz4IRiuLaWS*, *https://drive.google.com/file/d/0B3Ux9yzCG1hvd2htRUNacnFnRDg/view?pref=2&pli=1*

[34] *http://www.aleo-solar.com/pressrelease/aleo-solar-announces-expansion-with-cell-production-in-germany/*

[35] Working Group meeting, Hamburg PVSEC Sept 2015

[36] Interview by Alessandro Virtuani

Local-content requirements

The idea of alternatives to the EC's anti-dumping, specifically a local-content requirement, was discussed with the interviewees. Typically, in countries that use such rules, a benefit is conferred on companies that source a percentage of the value of their PV product locally, for example by building a plant in that country and employing workers, or by buying sub-components from local firms. The benefits might be access to incentive schemes like feed-in tariffs. The legality of such schemes under WTO rules is unclear, says steering group member Alexandre Roesch. Some, such as Ontario's, have been found to be illegal[37]. The fact that such rules are anathema to the EU, and that the EU uses the WTO to try to strike them down wherever they appear (says Solarworld) has not stopped this report's interviewees from finding them, generally, a much better form of mild protectionism than the EU's current anti-dumping rules.

Interviewee S said, "Local content is one of the best ways to protect local industry. […] Prolonging anti-dumping is not the best way defend EU industry."[38] Interviewee C said, "The general concept of local content is a very good one." He imagined a local content rule that would apply to an installed system: "To ask for local content is not unfair and does not have such a negative effect as a sanction has." They would be easier to apply to large projects because the cost of checking whether small systems, like 4kW home systems, comply is onerous compared to the benefit. Local content shares of 40-50% seem reasonable to him, while shares of 60-70% seem reasonable to Interviewee I. His company produces technology that relies on trackers, which can be made locally. His CPV colleague Interviewee I thinks 60 or 70% would not be a problem for his company. He is happy to leave companies to supply the steel and labour necessary for installation of his modules. Interviewee P calls local content "a wonderful thing. It's not an anti-export barrier because not all the jobs are for local people. It supports the local industry but does not totally ban foreign products." He thought Turkey's and India's applications of local content serve as good models, but since our conversation, the WTO ruled against India's model[39]. His enthusiasm is echoed in a press release by Schmid from 23 May 2016 announcing it would supply Iran with a turnkey 200 MW line from polysilicon to module: "Iran is progressing with its strategic plan to diversify the country's energy resources by increasing the share of renewable energies in the country's energy mix, putting major emphasis on technology ownership and highest degree of localisation."

Saudi Arabia invests in renewables, including PV, firstly for industrial policy reasons and secondly to get clean MWh of energy, says a member of the Middle East Solar Industry Association, MESIA. Mohammed Atif is area manager for the Middle East and Africa at DNV GL. Speaking of Saudi Arabia's King Abdullah City for Atomic and Renewable Energy, he said it was "a programme for industrial transformation on a national scale". As such, in his view, "from a long-term planning perspective — if I just look at it from a long-term, logical, policy perspective — there is some logic to there being a much slower build-up in the renewables programme, in order to allow this industrial capacity to develop within the country."[40]

But Alexandre Roesch used the example of Algeria as a country which is just beginning to familiarise itself with PV to say he was "really not sure" that local content rules help. In contrast to Saudi Arabia's approach, the focus should be on demonstrating the cost-effectiveness of PV, allowing it to "kick off a market", in his view. Paula Mints is also sceptical of the effectiveness of local content rules in building up local manufacturing capacity and Interviewee K is unpersuaded, too. Contributor H, meanwhile, writing in Nov 2014, went so far as to suggest that industry might "recently" have left Europe because "countries with PV emerging markets are putting in place incentives schemes or tenders for PV capacity build up requiring high (and increasing) local content." By implication he thinks they are effective.

Macro-level local content: build a plant

Interviewee F agreed to the suggestion that it would be better to achieve local content in a different way. Instead of an approach that aims to trace the origin of each component in a system, which is a fiddle and potentially cheatable, governments could go for a higher level kind of deal, where an investor builds a factory in return for government action to stimulate demand for PV. This happens in the wind industry in the UK, where specific pledges to invest in factories in the UK are negotiated alongside the size of government incentive schemes[41]. F said this was exactly his view, "All approaches like taxes can be circumvented […] so much better is to define local content by having a factory somewhere and a number of employees."

Quality as discriminator

Some believe that a hurdle related to quality is more appropriate than either tariff penalties or local-content requirements. Interviewee Q was one. He sees quality in part as a criterion by which public procurement programmes could discriminate in favour of European products: "Quality should be part of the anti-dumping regulations. Price can be manipulated. […] Like Japan, Europe should say it only wants panels of a particular quality and efficiency. Governments should act as a launching customer (e.g. every year buying 100 MW of 500 MW of output from a factory for public buildings, like China does. In stipulating tough enough criteria most of the Chinese production can be ruled out. […]"

Clearly some Chinese manufacturers fancy their chances or Interviewee D would not have said they give their support to his initiative for a quality label.

It is ironic that the feature of Japan's management of its PV industry that Q thinks Europe should emulate is identified as barrier preventing European manufacturers from selling their products on the Japanese market. [*Minerva 2014*] said, of balance-of-systems components like inverters, "The current regulatory framework differs from international standards and is thus one of the major constraints for market entry," adding that one body had a monopoly on certification, did not make public "specific test guidelines", and did not issue its documentation in English. It recommended that the European Commission raise these concerns in the "EU-Japan Industrial Policy Dialogue or even a wider framework, namely the ongoing EU-Japan FTA Negotiations".

More details on quality as a source of competitive advantage are available in the next chapter, 'Playing on Quality'.

[37] Statement in phone conference 23 August 2016

[38] Interview EUPVSEC Sept 2015

[39] *https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds456_e.htm*

[40] *http://www.rechargenews.com/solar/1422475/in-mena-lower-oil-prices-are-focusing-minds-on-renewable-energy*

[41] See for example *this press release by Gamesa*, which is careful to point out that "market developments" and "commercial opportunities" impact on the size of the investment it will make at its chosen UK manufacturing base

Playing on quality

Product-performance quality

Educating the public about the quality of PV products is the strong wish of many of the interviewees and of this report's steering group. "Quality has not been valued by the PV consumer," said Nitzschke. "When feed-in tariffs began stimulating demand in Europe," says Paula Mints, "capacity was struggling to meet demand. In response, tolerances began widening, quality standards began relaxing and there was a move to lower the industry standard 25-year module warranty to 10 years. Meanwhile, China was ramping up its production of crystalline cells and modules. In China, standards for quality in the PV industry and in others differ from other countries. During this period module quality levels were expanded to include A, B and C-graded modules. It became acceptable to buy modules with obvious defects."

Evidence for trends in quality from a statistically significant sample is difficult to come by, as few want to admit either to selling poor products, or to buying them. Potentially disinterested parties such as installers, do not want to speak on the record. Patchy anecdotal evidence is all that is available, and the complaints about quality, where they exist, tend to be directed at Chinese-made modules.

Qualification testing (e.g. IEC, UL) of PV components (e.g. modules, inverters) does not guarantee that a PV module is going to operate for 20-30 years without significant unexpected performance degradation. Interviewee G said, "IEC certification is only a base level. It will give you no safety for 25 years, for sure." And Alessandro Virtuani agreed, "We really have a lot of evidence about this [Editor's note: Alessandro used to work at the European Commission's Joint Research Centre and SUPSI which, among other activities, performed tests on PV products]. A lot of people were installing systems like crazy in the last years- Italy, Germany, Spain, etc. – and we see really that often the quality of the module was not there, even if qualified according to IEC." Interviewee C thinks, similarly to G, that just because a warranty on a module is for 25 years, this is no guarantee that it will last that long. Warranty length is therefore not a reliable indicator of quality: "Someone put a 20-year warranty on their model. Others followed, some with no reason to think their modules would last so long. Then people started putting 25 years and were joined by others. Warranties are a marketing-device, without a solid scientific basis." Nitzschke said, "We tell our customers to visit the production site if they are thinking of placing an order. Experience is better than paper."

As Interviewee D said, "People give you a guarantee of 25 years but what does that mean when the company is selling to you through various intermediaries? And no-one knows if the original supplier will still be there in 25 years." Contributor U: "Actually, all the products in the market have similar warranties, independently of the manufacturer and quality." Only Interviewee L entertained the idea that an extended warranty implied a better manufacturing process behind the product, giving the example of Centrosolar (now Solarwatt in Europe), which offers a warranty of 30 years, five more than the usual 25.

Aware of the danger facing the whole industry if modules on people's roofs fail in large numbers, D wants deficiencies in quality to be addressed across the module industry urgently: "We need to absolutely develop at European scale a true first label to inform consumers." The label would start off like the A++ to G energy rating system, allowing consumers to choose products that meet certain objective criteria related to environmental footprint and technological performance, but D imagines it could one day become a measure by which products are permitted or excluded from the market. The idea is gaining traction. It has support from Solar Power Europe[42] and the French government, which is the first government taking this line of thought in its assessment criteria for PV tenders (see below – next section).

[42] Letters to Commissioner Malmström: *Sept 2015*, *July 2016*

Playing on quality

Contributor H advises the EU to embrace a quality label based on tougher tests than those used to certify PV at present both for production equipment as well as for PV end-products (for commentary on the idea of standards in production equipment, see Anti-dumping, above). The tests should take in raw materials and the origin and sustainability of base components. Interviewee G, too: "To keep thin-film production in Europe, we could give a higher certified quality via a more advanced test [and independent testing]."

L felt that PV module buyers attached little importance to reliability. Solarworld thinks "Investors in ground-mounted systems want their money back in 6-7 years. They don't much mind if it underperforms after that, but if they did care, then they might be able to sell their development on. Private-household investors are also over-interested in the short term. We need consumers who are interested in the cost per kWh over the system's lifetime, not the cost per Watt-peak. We lack a salesforce that can tell as cost per kWh story."[43] D says the same thing. Better LCOE is the justification for investing in technologies that cost more to make and buy per Watt-peak. Nitzschke says, "Long-lasting modules would give those modules and the installations where they are used a resale value." But it's not quite as simple as that, warns Interviewee P, "The best LCOE is the standard technology because you have all the equipment, fully depreciated, or if you were to do an expansion you could buy that equipment at a very low price." (M acknowledges the point about discounted equipment: "[Chinese manufacturers] think that they only need to wait 3 years before we'll offer the tool at half the price.")

Box 4 – **Role of automation in quality assurance**

For Milan Nitzschke, automation is a way to reduce headcount, and so reduce cost. The company employs 3 000 people, "while 10-15 000 people would be needed for the same output in China. […] The asset that you create with automation is higher quality."

Others think Nitzschke might need to update his perceptions of Chinese headcount. In June 2016, Photon International reported IHS Technology's study on the competitiveness of Europe's manufacturers[44] as saying, "The degree of automation at production sites plays a marginal role [on the relative competitiveness of a range of Asian and non-Asian manufacturers] because they exhibit much the same level."

Interviewee F agreed: "Factories in different parts of the world now look similar." His view of the benefits of automation was more nuanced: "The industry has by now understood what kind of automation is useful, for quality for example, and what kind of automation is just overhead." He took the example of module junction boxes. If a module producer wants to switch over to a cheaper new version, workers can adjust to the new model within an hour, but robots might take much longer to reconfigure. He added, "In China automation is adopted to improve quality (aid to reproducibility) and slightly less because salaries are increasing." L also links "automated module assembly" to "product reliability".

Among those who see consider automation primarily to be a means to avoid labour costs are Contributor Z ("As industrial we need to produce a wafer, an ingot, a cells, a module with equipment as much automated as possible [because China is competitive on labour]") and D, who said automation was exposing his company less and less to labour costs.

[43] Statements at April 16 2015 EUPVTP St Cte, Brussels

[44] P.I. article 'The big players lead the race' – p43

Box 5 – **The 'Made in Germany' cachet**

While hard facts about China-made product being of inferior quality are hard to come by (if indeed they exist), purchasing decisions may be influenced by marketing arguments, not just hard evidence alone.

A 'Made in Germany' label on a product means it can be sold at a slightly higher price than some near-identical products made elsewhere. Emiliano Perezagua said Europe-made modules attract a slightly higher price on the world market than China-made ones of the same performance and Peter Wohlfart[45] agrees there's a small premium for 'Made in Germany' production equipment. 'Germany' is a by-word for quality, said Interviewee G, that gives the customer confidence. His company manufactured modules in Germany based on a less mature PV technology, CIGS, and needs to use every opportunity to boost confidence in its products. The CPV community (Interviewees C and I) agreed on Made-in-Germany's positive connotations, with Interviewee I adding that to improve the bankability of "relatively immature" III/V CPV technology, it is "especially helpful."

These remarks were made before the Volkswagen emission tests scandal.

Environmental footprint

Some companies would like the negative environmental impacts from the manufacture of a PV product to be taken into account. In June 2016, Andreas Wade praised the approach France took with its PV tenders. He wrote, "A recent tender for 200 megawatts (MW) of solar power placed a 15% evaluation premium on projects that used PV modules with low carbon footprints," and wanted other countries to follow France's lead[46]. D is a fan, too, and found it shameful that "a European consultancy had helped Yingli or Trina [Editor's note: he was not sure which] qualify for the [tendering round] by arguing that their use of Three Gorges electricity meant they complied with the CO_2 rule." Noting that "developers account for the majority of the downstream ecosystem", he said the majority of this ecosystem "in France, if not Europe, sees Chinese dependence, and is interrelated with Chinese interests. […] They are making profits by using cheap Chinese products and don't want to change their business model." The downstream ecosystem also includes ex-manufacturers, says Contributor U: "Most of the European manufacturers shifted the focus [towards] EPC and development." CEA-INES is promoting an EU Ecolabel that would extend the criteria taken into consideration in French tenders to include reliability and technical performance criteria as well as environmental indicators beyond CO_2[47]. Milan Nitzschke prefers the approach to "local content requirements" and hopes it could be applied wherever a PV installation benefits from a subsidy programme. ETIP-PV considers the "Minimisation [of] life-cycle environmental impact along the whole value chain of PV electricity generation [and the] increase [of] recyclability of module components" to be important aims for the European industry[48].

Interviewee E, whose company, like Wade's (First Solar), manufactures a thin-film technology, also welcomes the French approach. "We need to be on an equal footing CO_2 footprint. The glass from some regions is cheaper because they use dirtier energy to make it." He also thinks that thin-films will do well compared to crystalline silicon because they are intrinsically less energy-demanding.

But K is not a fan. He sees France's plan primarily as a measure to promote French-made products, because "nothing transported long-distance can make it." This is more or less explicitly acknowledged by the EU Ecolabel promoters: the label "could contribute to sustaining European photovoltaic industry because of high quality requirements." Nitzschke prefers to see this not as de facto exclusion of products, but as an opportunity for European PV producers to capture value that is not recognised by the world market.

[45] Statements in Munich WG meeting 13 June 2016

[46] European Energy Review, *http://www.europeanenergyreview.eu/france-pioneering-lower-carbon-solar-energy/#comments*

[47] *Presentation 17 May 2016*

[48] *Declaration of Intent* on SETIS

Attitudes to IPR

P said, "The Chinese are used to copy and think it is even an honour for the one who is being copied." China has a "just do it" culture, said Interviewee O, "They do not seek full understanding of physical basis before launching into production, while Europeans like to cross all the 't's and dot all the 'i's."[49] M said, "Chinese engineers are very keen and very fast. You need some breaks in the process: play with changes in temperature in the process 'to avoid recombination on the rear side'. Without knowing that, you would produce cells with slightly lower efficiency. If you install that and you speak with them and every day they learn 5 seconds of your know-how then if your know-how is one minute, after 10 visits, they know."

P, speaking on 24 August 2015 said his company would "soon sue the Chinese manufacturers and machine manufacturers that violate our IP. Our suit could be successful and have an impact and change a bit more the perception and respect towards IP." P thinks that publicly listed companies have a particular responsibility to abide by international rules on IP. Interviewee Q, of another equipment manufacturer, said China should respect IP rules ("That's number one.") but accepts the world as it is, "We know they will copy [our equipment]. It will take them a year. And then we will need newer technology."

Q's attitude is more common than P's (Box 6). Rather than protesting at Chinese IP appropriation after the event, other companies adopt policies to minimise it in the first place. Milan Nitzschke of cell and module manufacturer Solarworld said, "We are not in Asia because we must be one or one-and-a-half years ahead of our competitors. We must be able to protect our innovation for this time from copying (or at least, not make it too easy to copy)." The company is planning to allow third party access to its 'Technikum' (an in-house test centre featuring a pilot line for testing new equipment), but access is subject to NDAs "so that whatever results come out are not the next day sold to China."[50]

SMA, unlike Solarworld, does manufacture in China, at the site of its subsidiary Zeversolar. It was said that the fact that Zeversolar is a nearly wholly-owned subsidiary of SMA reassures the company that there is less chance of IP leaking out than if SMA used a OEM or was in a JV.

"The main know-how went to China with the equipment suppliers, but I do not complain," said C, "I think it's a very difficult decision not to cooperate in the way Europe cooperated as the Chinese capacities were built up." The "cooperation" has at times involved subtler action to protect IP than the approaches above:

Simultaneous patent filing

"The system for defending patents in China is more difficult to manage," said Interviewee F. J says his company's approach is to file patents simultaneously in China and Europe, but it makes its production equipment in China]. This makes it harder for its competitors to file something similar in China and steal the idea. "If you are facing fierce competition from Chinese companies and competitors then the PCT [Editor's note: a patent treaty accord spanning jurisdictions] takes too long," he said.

Sometimes companies prefer to protect the IP by secrecy and the use of proprietary technology (see Box 7).

[49] This may have led Interviewee L to say that European companies lack a "hunger" that you find elsewhere.

[50] EUPVTP steering committee Brussels 16 Apr 2015

Attitudes to IPR

Box 7 – **IP protection by secrecy and use of proprietary technology**

Mines Paristech says its "interviews suggested that Chinese innovation focuses more on process, which is often not carried out in specific R&D departments but directly on the production lines, and protected by secrecy rather than patenting." It mentioned this in connection with polysilicon (see earlier, Competitive analysis of China). Interviewee N, another polysilicon supplier, agrees with the analysis. Speaking in Sept 2015, he said, "To know how to efficiently operate Si production technology takes a lot of skill."

That supplier uses proprietary technology that has allowed it to "keep improving the productivity of our process, including by getting energy consumption down by double-digit %." Two other companies interviewed also both use proprietary technology. E: "There is little core equipment for our tech. We have to make it." Interviewee I: "We buy basic reactors, then we modify and make own processes."

Separate R&D from production

Transnational PV companies hunt for the best of both worlds: "Stronger IP protections may make the U.S. an attractive location to commercialise a disruptive c-Si PV technology, while China's track record of rapidly scaling-up new technologies may make it attractive," said [*MIT-NREL* 2013], "Some leading PV manufacturers have noted that "intellectual property rights and confidentiality protections in China may not be as effective as in the United States or other countries." Some companies have kept their R&D out of China. Reasons for this include the following:

The distance between the R&D scientists and the process engineers allows each to concentrate on their tasks better

Interviewee G (whose company, at the time of speaking, was finalising the construction schedule of a large fab in China): "If your R&D is on production, it's good to be close. But if you aim your R&D a little further ahead, it's good to have some distance." He said R&D personnel should not be dragged into the daily problems of production, which is what would happen If they were together. "We've tried different levels of exchange. Now that we are half-mature, the interaction does not need to be so quantitative-wise big."

Better chance of IP protection

J: "Totally new approaches – which means, we are currently expanding to offer special cleaning machines – come 100% out of our European base, 100% from Germany. Our manufacturing centre in China is kept without a clear insight in the overall production process."

"My company would always keep its core technology at its European HQ," thinks Interviewee K.

On the other hand, a manufacturer of inverters and other electrical components in various places around the world that is run from the Far East, is content with China's attitude to IP. It is by chance that the company's R&D centres for PV inverters are in Germany and two different Far Eastern countries, while manufacturing is in China and Taiwan. Other parts of the business do have R&D in China, for example parts related to energy storage and conversion. "As a corporate we are quite well protected in IP rights, even in China, so I cannot see any high risk in that area."

Culture of innovation in 'the West'

Interviewee W might have been thinking about his specific sector, BIPV when he said, "Europeans are much more creative than the Chinese (I use 'Chinese' metaphorically). We're the designers. We think things through to the end. Europe will be the source of creativity." Interviewee L had the same view, thinking China is not innovative culturally.

E's company is only in pilot production and continues to invest heavily in R&D. The manpower close to the production plant is good. He is less certain about where its R&D department would be located once his technology goes into mass production.

G suggests that his company's key R&D staff are in Europe: "The idea to move R&D to China I'm sure exists, but I don't think the key staff will move to China."

Keeping production in Europe even if the mother company is Chinese

Elkem's owner since 2011 is the China-based international chemicals and new materials company Bluestar. Bluestar choose to keep Elkem's production of compensated silicon in Norway because, said a representative, it does not want to run the risk of "five competitors nearby in China copying the process. If the European plant discovers an improvement, within six months the industry in China will know the concept but might not know how to build the EU-style plant." Elkem was the only company to use an IP-protection reason for keeping production in Europe, but other interviewees (e.g. G) saw the logic of it when it was presented to them.

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