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Perspectives on future large-scale manufacturing of PV in Europe

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Abstract

The growing global PV market continues to present substantial business opportunities for Europe. The question is now: what role could or should European manufacturing industry play in these developments? The European Photovoltaic Technology Platform's position paper released at the end of 2013 makes a clear case for re-launching Europe's PV manufacturing sector. Several groups are actively prompting plans and seeking funding for such developments, for both crystalline silicon and thin film technologies. This report summarises information on the range of factors that may influence the prospects for realising these ambitions

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Annex 1 Position Paper on the Future of the Photovoltaic Manufacturing Industry in Europe

EXECUTIVE SUMMARY

European industry played a key role in the rapid growth of PV over the last decade. The manufacturing sector (including production equipment) reached a peak turnover of approximately €20bn, and about 260 000 direct jobs in 2010. However in 2014, this turnover has declined to €2.5bn, due to both the sharp decrease in the price of PV and to a shift of cell and module production to Asia.

At the same time the growing PV market continues to present substantial business opportunities.. It is estimated that in 2030 PV could supply up to 15% of the overall electricity demand in the EU, about 7 times more than today. The IEA predicts that global cumulative installed capacity of solar photovoltaic electricity systems will more than triple from 2013 to 2020, reaching over 440 GW.

What role could or should European industry play in these developments? Several research consortia are actively prompting plans and seeking funding for such developments, for both crystalline silicon and thin film technologies. The Round Table discussion on "Scientific Support to Europe's Photovoltaic Manufacturing Industry" organised by JRC and ENER in January 2015 confirmed this interest - the resulting position paper from the participants is included here in Annex 1.

This report looks briefly at a range of factors that can influence the prospects for realising these ambitions. The main findings include:

- PV manufacturing is transforming into a mass-producing industry with its sights on multi-GW production sites. This development is linked to increasing industry consolidation, which presents a risk and an opportunity at the same time. For small and medium companies to survive the price pressure of the very competitive commodity mass market and offset the economies of scale enjoyed by bigger competitors, they will need to develop products with high added value or tailor-made solutions. The alternative is to offer technologically more advanced and cheaper solar cell concepts.
- For a large-scale manufacturing initiative to be economically viable and to have impact on the global market it would need to aim for a capacity of several GW. This reflects the importance of economies of scale and also having a production volume sufficient to impact an annual EU market of at least 6 GW and a global market of 50 GW. It would need to meet a short-term module cost price target of below EUR 0.40/W and have a credible plan for further reduction. This reflects the reality that product differentiation is based primarily on price, and is expected to continue to be so in the medium term. Finally it is essential to involve partners with the expertise to successfully operate GW fabs. PV technology expertise alone is not sufficient.
- To best mobilize EU resources, such an initiative should involve several European countries and regions and include a range of technologies and product forms.

Finally, while PV electricity is increasingly competitive, it remains a sector driven by policy at both national and EU levels. The size and growth potential of the EU "home" market is also important for module manufacturing/assembly location. To reverse the currently contraction of the PV system installation market and enable it to grow again requires a major effort across the EU to ensure a stable investment environment and to reduce soft-costs and administrative barriers.

1. INTRODUCTION

The European Union has set out plans for a new energy strategy based on a more secure, sustainable and low-carbon economy. It has committed itself to achieve at least 27% share of renewables by 2030 with the aim of encouraging private investment in infrastructure and low-carbon technologies.

Photovoltaics are expected to make a significant contribution to achieving this goal, as being the renewable energy technology with the largest scope for cost reduction and efficiency gains. The global PV industry grew an average about 50% per year over the last 10 years, and has reduced costs four-fold in the same period. Currently the EU member states have an installed capacity of approximately 88 GW and in 2013 PV already provided about 2.7% of Europe's electricity needs. It accounts for around 9% of all electricity generated by renewables (which includes hydro, biomass and wind). Leading EU countries for PV power generation are Germany, Italy and the UK, with significant increases noted in Romania (in 2013) and in Bulgaria (in 2014) [1]. Nonetheless, PV remains a sector driven by policy at both national and EU levels.

Looking forward, experts estimate that in 2030 PV could supply up to 15% of the overall electricity demand in the EU, about 7 times more than today. At a global level, the IEA Medium-Term Renewable Energy Market Report 2014 [2] estimates that cumulative installed capacity of solar photovoltaic electricity systems will more than triple to over 440 GW by 2020 compared to 2013.

Therefore significant business opportunities exist right across the PV value chain, from production through to development and operation of installations. European industry played a key role in the rapid growth of PV over the last decade. The manufacturing sector (including equipment) reached a turnover of approximately €20bn, and about 260 000 direct jobs. However in 2014, this turnover has declined to €2.5bn. Indeed most of today's global PV manufacturing is located in the PRC and Taiwan, but capacities in Japan, Korea, Malaysia and Philippines are continuously increasing. In 2013 Asia as a whole accounted for more than 80% of the world's production share and Europe held only 3% (while in 2008 Europe's global share was 26% and Asia's 63%).

The question is: what role could or should European industry play in the enormous future market for PV products? What policy measures would be appropriate? In 2014 European Commission President Juncker declared that the EU should become the world number one in renewable energies, as a matter of a responsible climate change policy but also an industrial policy imperative. This commitment was confirmed in the Energy Union Package communication in February 2015 [3].

The European Photovoltaic Technology Platform's position paper released at the end of 2013 [4] makes a clear case for re-launching Europe's PV manufacturing sector. Several groups of research institutes are actively prompting plans and seeking funding for such developments, for both crystalline silicon and thin film technologies. The stakeholder input [5] to the new SET-Plan integrated road-map clearly targets "LAB-to-FAB" issues. It also draws attention to the mitigation of risk and financing for large scale multi-gigawatt manufacturing as a key aspect to provide a sound and competitive basis for the European PV industry, and the need for schemes to move from pilot production into large scale industrialisation".

In 2014 DG-ENTR (now DG-GROW) released a study commissioned from ICF International on competitiveness of the EU renewable energy industry, including solar PV [6]. While cautiously optimistic for the sector as a whole, and in particular for the downstream side (project development and operation), the analysis also highlighted some of the challenges facing manufacturers: *"Those EU companies that manage to survive the current turmoil in the solar PV market will clearly be better placed to compete globally and are worthy of investigation into*

strategies for success. However, the sector is still undergoing transition. China's tier one PV module manufacturers are on track to cut production costs from \$0.50/watt to US\$0.36/watt by the end of 2017 – a cost not thought possible but now conceivable with the help of new innovations as well as automation".

In January 2015 the JRC, with the support of DG-ENER, organised a round table on "Scientific Support to Europe 's Photovoltaic Manufacturing Industry" in Brussels". One outcome was that a group of representatives from industry and research produced a position paper (30/03/2015) on "the Future of the Photovoltaic Manufacturing Industry in Europe", which was reviewed by JRC. According to this, support should focus on;

- A. Upgrading existing crystalline silicon manufacturing capacities at Gigawatt
- B. Establishing manufacturing facilities at Gigawatt size
- C. Research and demonstration in a wider field of emerging technologies
- D. Smart integration of PV systems in energy systems can reduce costs and facilitate the handling of fluctuating electricity generation.

In particular the paper proposed a task force to develop an action plan on "Financing and Business Opportunities". The full document is included here as Annex 1.

In the following we take a closer look at developments in PV manufacturing and provide information and perspectives on factors which can influence its future development in Europe.

2. PV INDUSTRY

2.1. Solar Cell Production Capacities

The JRC's PV status Report 2014 [1] has analysed global PV cell¹ production from 2005 to 2013, based on data collected from stock market reports of listed companies, market reports and colleagues. While the global market has increased steadily to 40 GW in 2013 (Fig. 1), the volume of EU cell production has decreased dramatically, falling from a peak of over 5 GW in 2010/11 to below 2 GW in 2013. Similarly its relative importance has dropped from about a third of global production in 2008 to 5% in 2013. This contrasts with the rise of Asia producers, in particular in China and Taiwan. For 2014 a further increase between 10% and 25% is expected by different consultancies.

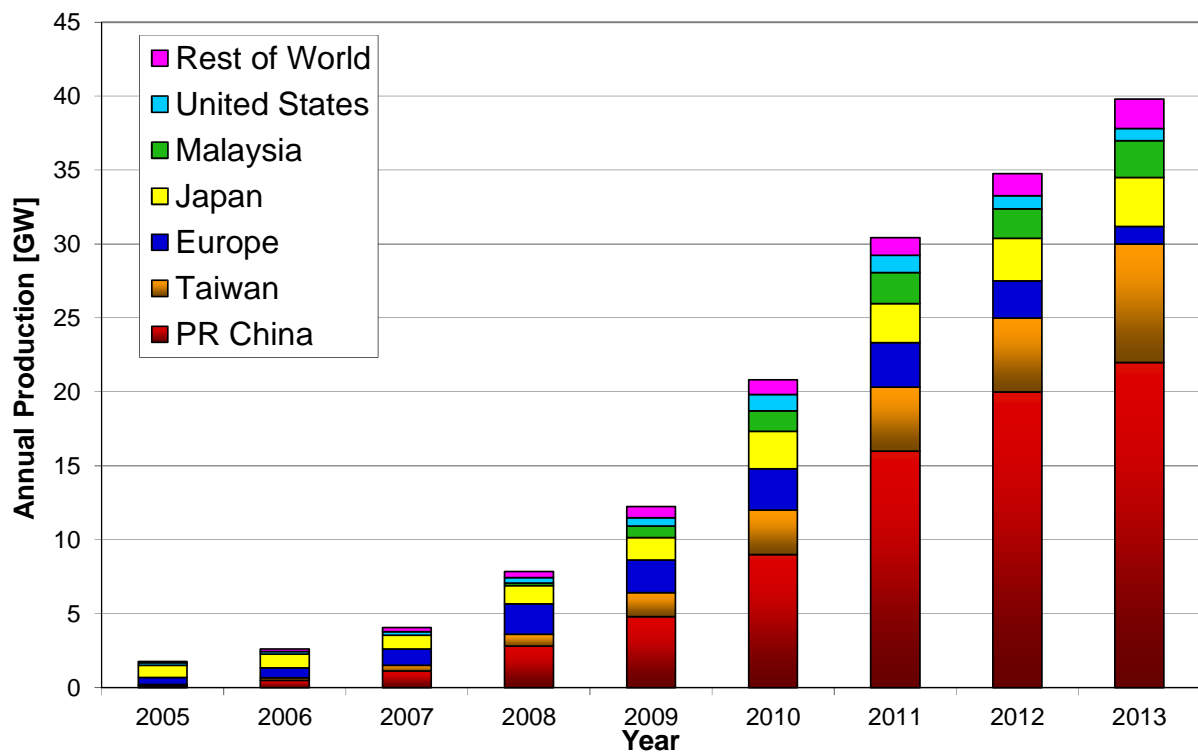


Fig. 1: World PV cell/module production from 2005 to 2013 (data source [1]: Photon International, PV Activities in Japan 2014, PV News and JRC analysis).

¹ Solar cell production capacities mean:

- In the case of wafer silicon based solar cells, only the cells,
- In the case of thin films, the complete integrated module ,
- Only those companies which actually produce the active circuit (solar cell) are included,
- Companies which purchase these circuits and make cells are not included.

Of the other traditional PV technology leaders, the USA also experienced a decline in manufacturing capacity from 2 GW in 2011 to about 1 GW in 2013.

Japanese production, on the other hand, has continued to expand, thanks to strong policy measures and subsidies to promote renewables in the wake of the Fukushima nuclear accident.

Amongst the 20 biggest cell/thin film PV manufacturers in 2013, only Hanwha Q CELLS (South Korea, Germany, Malaysia and China) still has production facilities in Europe (however it has subsequently announced that it is pulling out of Germany and shifting production to Malaysia and Korea).

There is some uncertainty – the data for 2013 varies between 35 GW and 42 GW. This is due to the highly competitive market environment, as well as the fact that some companies report shipment figures, while others report sales and again others report production figures. In addition, OEM manufacturing² increased significantly adding to the uncertainties in production counting. 2013 was characterised by a shift of the main markets from Europe to Asia, mainly due to increased demand in China and Japan.

The annual production capacity of cell manufacturing lines has typically increased by an order of magnitude over the last decade, from tens to hundreds of megawatts per year. The first GW-scale plants have been set-up in Asia and several others are in the pipeline.

There is a considerable international trade in cells, which can be transported reasonably cost effectively and then assembled into modules in a process which involves lay-up and interconnection of the cells, encapsulation together with a back sheet and front glass, and then edge-sealing or framing.

2.2. Module Production

The above data refer to essentially cells, not modules i.e. the final assembled product (an exception is for thin film products, but these make up only 10% of the market at present). Cells are considered the most reliable basis for estimating production, whereas module data are more difficult to establish reliably. Nonetheless various trade side and consultancies monitor the largest module producers – Fig. 2 shows the top 15 in 2013 from the IHS consultancy [7]. All are Asia-based with the exception of First Solar (USA). The top-ten all ship more than 1 GW of module annually and represent about 45% of the total market. The production itself is typically split over several sites, with individual lines of the order of hundreds of MW. The scale however is increasing rapidly, as evidenced by SolarCity announcement last year of a 1 GW fab in Buffalo, New York state, while more recently Hanwha Q Cells confirmed capacity expansion plans that include the construction of its solar cell production facilities in Korea with a nameplate capacity of 1.5GW.

Furthermore, although some manufacturers may differentiate products based on performance, reliability, and appearance, the vast majority of manufacturers produce “off-the-shelf” technology.

² Original equipment manufacturer (OEM) is a term used when one company makes a part or subsystem that is used in another company's end product

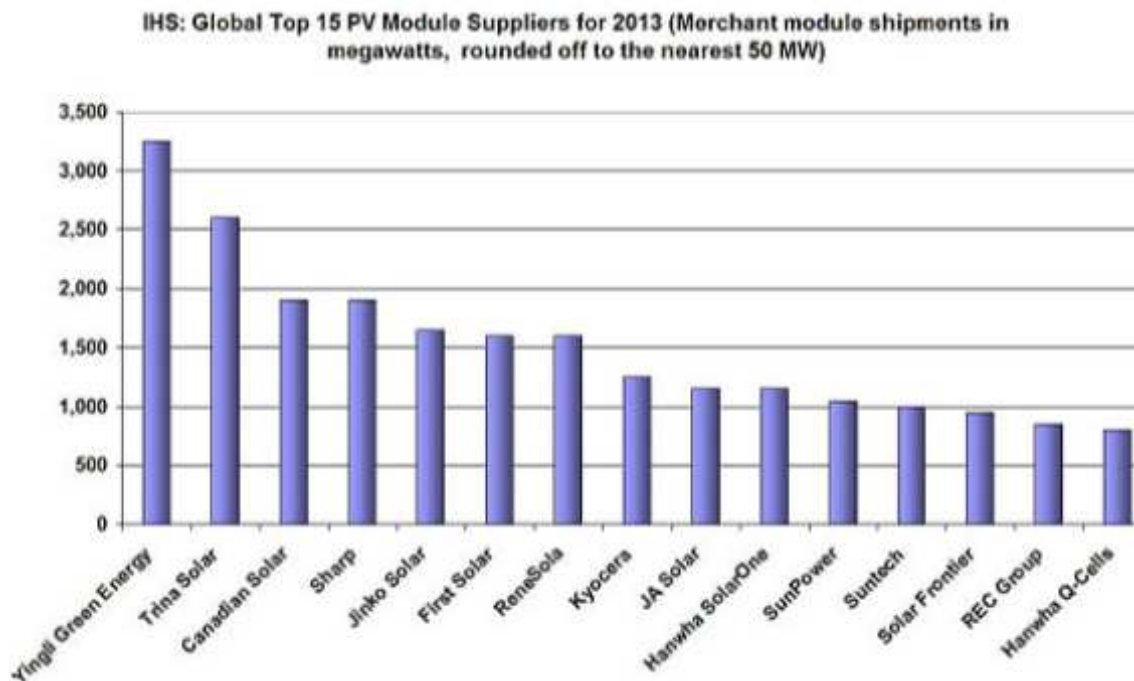


Fig. 2: IHS consultancy: top 15 PV module producers in 2013 [7]. The IHS data for 2014 (no comparable graph is available) show that Trina Solar took over the top spot from Yingli, with shipments in the region of 3.6 GW. They put the total 2014 module market volume at 48 GW.

The absence of European companies reflects the severe shakeout which has occurred over the last five years. Many were squeezed out of the market by the intense competition from low-cost modules produced in China and other Asian countries. The ensuing anti-dumping cases in Europe and the US are well-documented. Others lacked financial resources to compete in the face of intense price competition, small or non-existent margins and a contracting domestic market. As a result many have gone out of business or been sold to international investors.

JRC estimates that EU module production capacity is currently at approximately 2 GW. Although a part of this is made up of smaller producers (typically < 100 MW) with niche products (including BIPV), there nevertheless remain some significant European players in PV manufacturing:

- SolarWorld AG develops and produces solar technologies. The company produces silicon wafers and manufactures solar cells and complete solar modules and components used to generate solar energy. SolarWorld also recycles silicon and by-products from solar wafer production. Current production capacity worldwide (Germany and USA) is >1GW, including a 500 MW fab in Freiberg, Saxony.
- Jabil Circuit (US electronics manufacturing conglomerate) has a module assembly plant in Poland, reportedly with a capacity of around 1GW. This has been used by ReneSola to provide modules into the EU that avoid import duties and limits to shipment quotas from its manufacturing plants in China.
- According to unconfirmed press reports, Recom AG (Athens, Greece) has announced that it will begin solar photovoltaic (PV) module production in Europe and that its manufacturing capacity in Italy is scheduled to exceed 500MW. The company has so far manufactured modules solely in Malaysia

2.3. The Value Chain

Fig. 3 illustrates the overall PV value chain. PV modules make up slightly less than 50% of the capital cost of utility scale systems, and approximately 40% for residential systems. Europe still has a good position in other parts of the value chain. In 2011, the European share in manufacturing equipment was well above 50% and the same holds true for operation and maintenance (70%), construction (70%) installation (70%) inverter manufacturing (70%), balance of plants (70%) and financial services (70%). However, if no revitalisation of the local market takes place this will fade away (see also section 2.4 on jobs below).

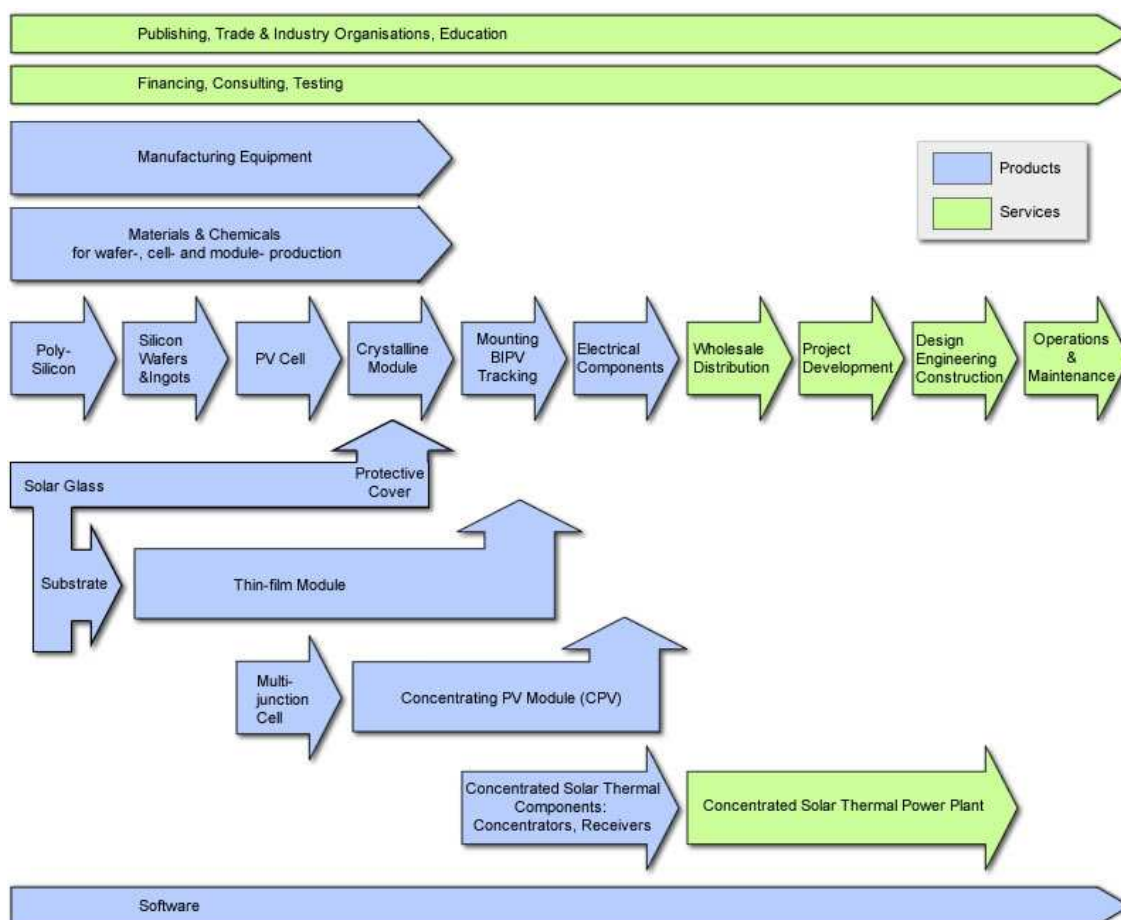


Fig. 3: Solar industry value (data source: GreenRhinoEnergy)

2.4. Jobs

Table 1 provides a detailed breakdown (JRC estimates building on original data from Bloomberg New Energy Finance) of the jobs associated with the global PV market in 2011 and 2013, as well as the European share. Most of these are in two main areas: a) construction & installation³ and b) cell & module manufacturing. To calculate the jobs/MW, employment figures and annual output stated in annual reports of public companies as well as private communications with private ones were used. Jobs in the general supply chain such as mining, glass manufacturing or supply of general equipment were not considered. Also those in production equipment manufacturing industry and public R&D are not included.

The growth of the PV industry in Europe resulted in a peak of over 260 000 jobs in 2011. More than 75% were related to operating and installing PV systems and almost all of these jobs were local, contributing to the European gross national product.

The steep drop in new installations from 2011 to 2013 has more than halved these local jobs and hence also their benefits to the local economy. In addition, the changes in the module and inverter manufacturing sector has significant consequences. If these industries contract further, the willingness for public R&D weakens and with it the ability of the equipment manufacturing industry to innovate fast enough to stay competitive and to provide the next generation of equipment needed for further cost reduction. However, these job effects are much more difficult to quantify and as a result are often neglected in the overall assessment of the sector.

³ "Construction" covers the labour need for large projects, whereas "installation" reflects the higher labour intensity of decentralised smaller installations.

Table 1: PV Jobs in the EU in 2011 and 2013 (JRC estimates building on original data from Bloomberg New Energy Finance)

2011	MW	Jobs per MW	Total Jobs	European Share	
				%	Jobs
Operation and maintenance	42,000	0.15	6,300	70	4,410
Construction	7,000	3.20	22,400	70	15,680
Installation	20,000	9.80	196,000	70	137,200
Polysilicon	31,000	0.75	23,250	25	5,810
Cell and module manufacturing	35,000	9.60	336,000	10	33,600
Inverters	27,000	1.50	40,500	60	24,300
Balance of plant	27,000	1.80	48,600	70	34,020
Project development	14,000	0.45	6,300	50	3,150
Financial services	27,000	0.10	2,700	70	1,890
TOTAL			682,050	38%	260,060

2013	MW	Jobs per MW	Total Jobs	European Share	
				%	Jobs
Operation and maintenance	100,000	0.15	15,000	57	7,350
Construction	18,000	3.20	57,600	20	11,520
Installation	20,000	8.90	178,000	30	53,400
Polysilicon	40,000	0.50	20,000	25	5,000
Cell and module manufacturing	42,000	8.00	336,000	5	16,800
Inverter	38,000	1.3	49,400	40	19,760
Balance of plant	38,000	1.5	55,500	30	16,650
Project development	36,000	0.35	7,000	35	2,450
Financial services	38,000	0.10	3,700	35	1,300
TOTAL			722,200	19%	134,230

2.5. Very Large-Scale Manufacturing (Giga-Fabs)

The PV industry is transforming into a mass-producing industry with its sights on multi-GW production sites. Already in 2010 REC's Singapore solar facility was opened and produced 722 MW of solar panels in 2012. The total investment was €1.3bn. For the last few years the leading manufacturers have been able to expand production capacity by re-branding existing lines and effectively mopping up the excess capacity created in the rapid expansion of 2008-2012, this phase may be ending. The move towards very large scale fabs on "green-field" sites is seen as inevitable in order to create the economies of scale needed to further reduce down prices. As mentioned earlier (section 2.2), in 2014 SolarCity announced of a 1 GW fab in Buffalo, New York state.

This scale factor and the expertise needed to implement and operate such fabs successfully need to be considered in any plans for new manufacturing units.

Several studies have been made on this subject. In 2013 the Baden-Württemberg Ministry of Environment, Climate and Energy commissioned a feasibility study from a consortium of several Fraunhofer institutes [8]. Released in December 2013, it concluded that it is indeed possible to produce innovative technology cost-effectively in Germany and Europe, with in a gigawatt-scale factory for an investment of €1bn and a project module cost of €0.40/W. The study included detailed analyses of the benefit of up-scaling product for two crystalline technologies (PERC and BSK) and for CIGS. Fig. 4 shows an example of the results, indicating the potential savings with respect to a hypothetical 500 MW baseline plant. Moving to 2 GW leads to approximately an 8% reduction in module cost. In the analysis PERC was preferred as having the lowest technological risk and hence WACC for the fab investment.

The NREL-MIT study [8] comparing US and Chinese production costs and released in 2013 also considered scale-up from 500 MW to 2 GW in combination with technology innovations. Together these effects produced predicted module cost reductions of over 33% (Figure 5).

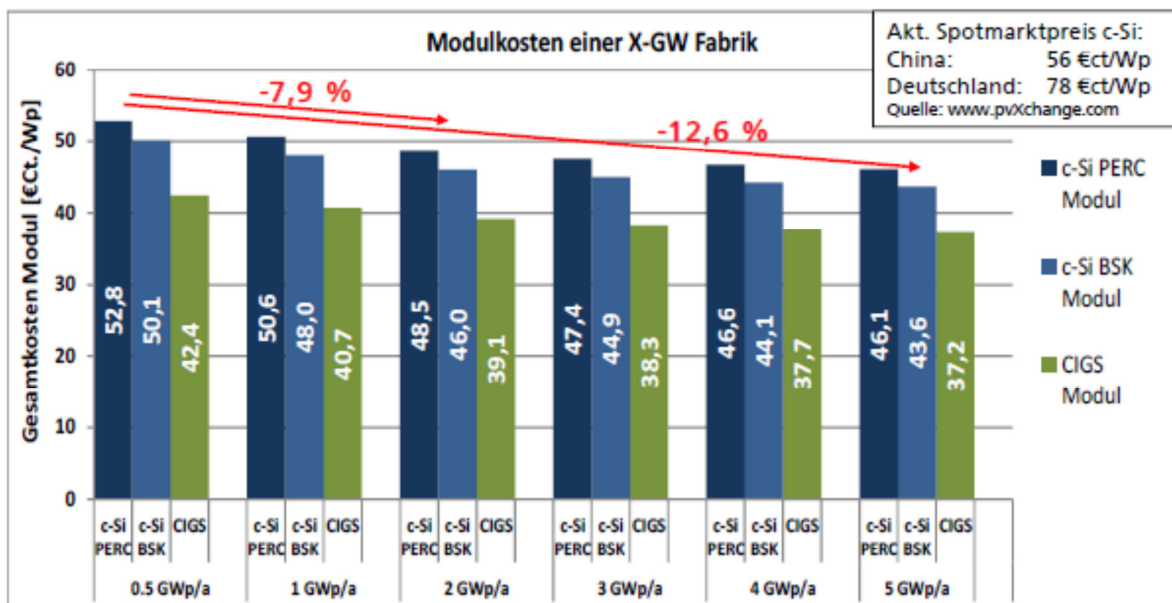


Fig. 4: Scale of production effect on module cost for three technology options [8]. PERC = Passivated Emitter Rear Cell; BSK is "beidseitig sammelnd und kontaktierbar" i.e. a double-sided emitter cell concept with contacts on both surfaces, which also makes use of upgraded metallurgical grade silicon (UMG-Si) with purity down to 99.999%; CIGS is a copper indium gallium di-selenide thin film device.

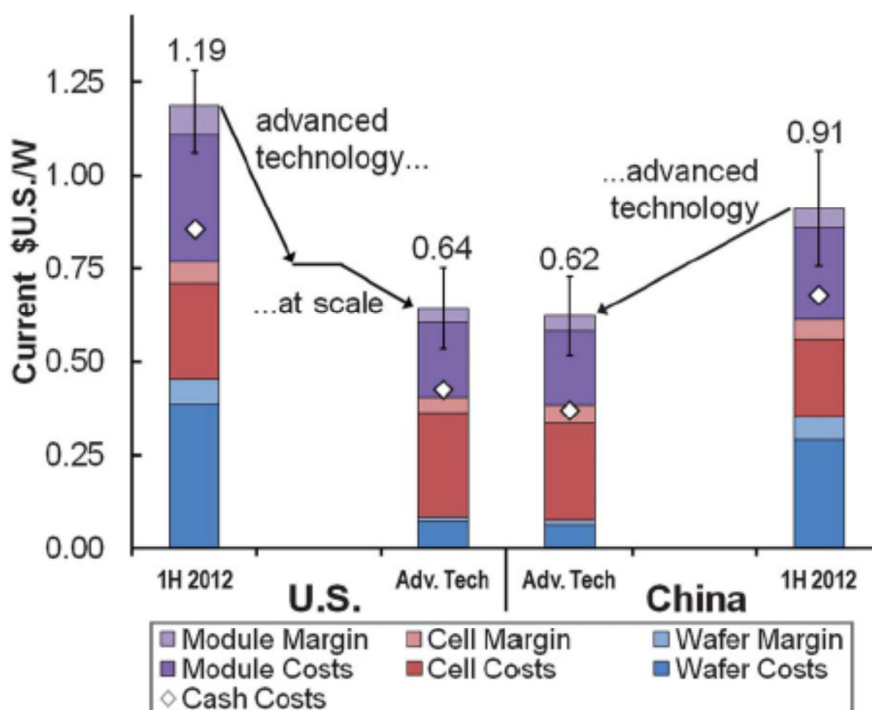


Fig. 5: The NREL-MIT study [9] shows potential impact of plant scale-up from 500 MW to 2 GW on production costs of advanced technology modules in the US and China

2.6. Background to China's rise as Leading PV Supplier and Installer

In the middle of the last decade, China and Taiwan anticipated large growth rates in PV and planned massive capacity expansions (Europe's most ambitious planning phase was in 2008, but declined due to the effects of the financial crisis on the availability of funds to finance the expansion plans).

Already during the China Development Forum 2003, it was highlighted that China's primary energy demand will reach 2.3 billion toe in 2020 or 253% of the 2000 consumption if business-as-usual occurs. Renewable energy was identified as one of the pillars to ease this pressure and presented a reason to press for additional Government policies supporting the use of renewable energy sources.

In 2005 the Standing Committee of the National People's Congress of China endorsed the Renewable Energy Law, which went into effect in 2006. At the same time the government set a target for renewable energy to contribute 10% of the country's gross energy consumption by 2020, a huge increase from the then 1%. The 12th Five-Year-Plan was adopted 2011 and in this plan renewable energy and PV electricity as a Key Technology was earmarked for USD 700 to 800 billion, intended to trigger USD 2,000 billion in investments for the six so-called GreenTech technologies. In 2012, the National Energy Administration (NEA) released the renewable energy five-year plan for 2011 to 2015. This called for renewable energy to supply 11.4% of the total energy mix by 2015. Renewable power capacity was planned to increase to 424 GW, with solar contributing 21 GW. In early 2015 the total was already at 33 GW. Indeed 2014 the National Development and Reform Commission (NDRC) approved an "Air Pollution Prevention Plan", which stipulates a 70 GW solar PV power generation capacity target by 2017. It's widely expected that installed capacity will exceed 100 GW by 2020. Even at this rate of domestic installation growth, its production capacity is higher.

3. PV MARKETS AND PRODUCTS

In considering the future development of PV manufacturing, clearly the projected markets need to be carefully analysed in terms of size, location and product-breakdown.

3.1. Projected Global and European Markets

At global level, estimates for the growth of the PV market are positive. The IEA's baseline scenario in its 2014 Medium-Term Renewable Energy Market Report [2] forecasts almost a tripling of the PV installations until 2020, with approximately 40 GW being installed annually worldwide. However, their predictions for the European market the annual growth rate flattens out to approximately 6 GW (Table 2). The IEA Energy Technology Perspective hi-REn Scenario, as reported in its 2014 Technology Roadmap Solar Photovoltaic Energy [9] (Table 3) the European market maintains a similar volume, but its worldwide market share shrinks from almost 60% in 2013 to less than 5% in 2050.

The projections [10] from the European Photovoltaic Industry Association (rebranded as SolarPower Europe in May 2015) are more optimistic (Fig. 6). However the large range from the low to high scenario (a factor of 2) underlines that, while PV electricity is increasingly competitive, it remains a sector driven by policy at both national and EU levels. Changing current contracting trend of the PV system installation market and enabling it to grow again requires a major effort across the EU to ensure a stable investment environment and to reduce soft-costs and administrative barriers. For this change to a more market driven environment, the EU PV manufacturing sector needs to have a level playing field in financing compared to international competitors.

The size and stability of the EU "home" market is also important for module manufacturing/assembly location. The 2013 MIT-NREL study [8] puts transports costs (Asia to US) at US\$0.03 to 0.05/W i.e. between 5 and 10% of total cost. Hence an EU-based module manufacturing model aiming predominantly for export is unlikely to be successful.

This message is reinforced by recent developments in the US and North America. The trade press (PVTECH, 17 November 2014) reports that 10 module manufacturers have announced new production plans for US locations, totalling just below 2GW in nameplate capacity. Future demand requirements and the preliminary US anti-dumping ruling have a good part to play in some of the decisions. However also European-based SolarWorld is part of this, and has committed to expanding capacity by 530 MW after completion and ramp in 2015.

3.2. Market Innovation

The market for PV products can be broken down into 2 main categories:

- Utility-scale systems: plants typically greater than 1 MW designed purely for supplying the grid.
- Rooftop systems: typically installed on or near buildings, with some part of the consumption being used directly on site. This category covers a wide range of sizes, from residential roofs with systems of a few kW to larger commercial roofs or adjacent structures, with system sizes up to 1 MW.

Table 2: IEA analysis of PV installed and project capacity by region [2].

	2013	2014	2015	2016	2017	2018	2019	2020
OECD	110.1	132.6	153.9	174.4	191.4	207.6	224.6	242.2
OECD Americas	13.9	19.7	25.5	31.8	36.1	41.0	46.5	52.6
OECD Asia Oceania	18.7	27.6	35.5	42.7	48.7	53.5	58.3	63.2
OECD Europe	77.5	85.3	92.9	99.9	106.6	113.1	119.7	126.4
Non-OECD	27.2	43.7	60.4	78.1	97.3	118.0	139.1	161.1
Africa	0.2	0.9	1.3	2.1	3.7	5.0	5.9	6.7
Asia	4.2	6.1	8.5	11.1	14.2	17.6	21.4	25.6
China	19.6	32.9	45.9	58.9	71.9	85.9	99.9	113.9
Non-OECD Europe	3.0	3.3	3.7	4.1	4.4	4.9	5.4	5.9
Non-OECD Americas	0.2	0.3	0.6	1.1	1.5	2.2	2.9	3.9
Middle East	0.1	0.1	0.3	0.8	1.6	2.4	3.5	5.1
Total	137.3	176.3	214.3	252.5	288.7	325.6	363.6	403.3

Note: grid-connected solar PV capacity (including small distributed capacity) is counted at the time that the grid connection is made, and off-grid solar PV systems are included at the time of the installation.

Source: IEA analysis; 2013 data are IEA estimates based on IEA-PVPS (2014b), *A Snapshot of Global PV 1999-2013*, IEA-PVPS, St. Ursen, Switzerland.

Table 3: IEA long-term projections for PV installed capacity in GW [10]

Year	US	Other OECD Americas	EU	Other OECD	China	India	Africa	Middle East	Other developing Asia	Eastern Europe and former Soviet Union	Non-OECD Americas	World
2013	12.5	1.3	78	18	18	2.3	0.3	0.1	1.4	3	0.2	135
2030	246	29	192	157	634	142	85	94	93	12	38	1721
2050	599	62	229	292	1738	575	169	268	526	67	149	4674

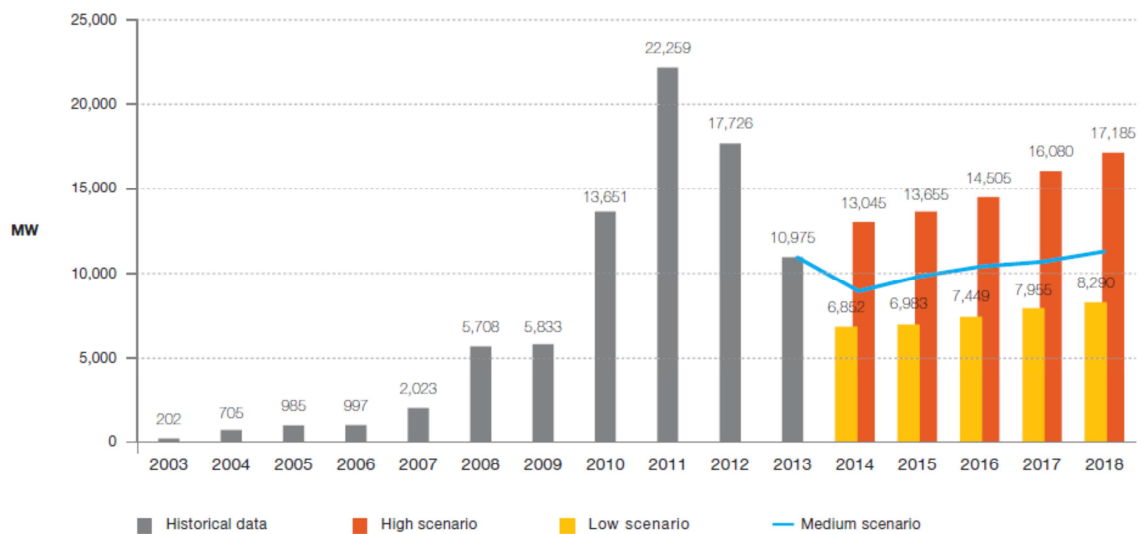


Fig. 6: EPIA EU market outlook for 2014-2018 [11]

EPIA's average projections for these two categories (Table 4) suggests that in Europe the rooftop market will become substantially larger than that for utility scale plants, whereas globally the situation is more balanced. The IEA takes a similar position regarding the breakdown of the global market. It also stresses the importance of the commercial rooftop sector.

Table 4: EPIA's predictions (low-high average) for PV market category breakdown in GW [11],

	Europe		Global	
	Rooftop	Utility scale	Rooftop	Utility scale
2014	4.3	4.2	25.2	18.2
2018	9.0	3.5	28.0	25.8

Both of these categories are currently addressed by the classic "module" product, with rectangular shape and an area of approximately 1.5 m². The power of each design varies somewhat according to the efficiency of the PV technology used (polycrystalline silicon, monocrystalline silicon, thin film etc.). However the product differentiation is based primarily on price, and is expected to continue to be so in the medium term.

Moreover the existing market for large systems is dominated by a limited number of companies who have developed "bankable" products and strong links to project developers, ensuring competitive project financing. For residential installations a "know-brand" product is of high importance to many local installers. Obtaining a significant market for a new product means addressing these challenges.

At the utility scale, scope for product form innovation lies mainly in the module size. One route is by introducing very large modules (>4 m² area), and more cost effective, automated mounting systems. In 2009 Applied Materials presented prototype 5.7 m² modules, but the concept wasn't fully developed commercially at the time. A medium-term strategy may be to move away from modules to strip-type products e.g. mass produced on roll-to-roll devices using thin film technology. Considerable European R&D is already being devoted to such concepts.

For the rooftops category, there is potentially considerable scope for product innovation, particularly if one includes building integrated PV (BIPV). Aesthetics and public acceptance may also become important factors. BIPV has long been tipped as the next big growth sector for PV products, but a series of factors including costs and lack of standards have hampered progress. While the online Energy Focus (ENF⁴) register lists 40 European producers of "innovative panel designs", covering roof tiles and shingles, PV thermal and transparent products, manufacturing is still small scale. Some new initiatives include:

- BOD Group, Via Solis and Baltic Solar Energy have set up the SoliTek manufacturing facility in Vilnius, Lithuania to produce, amongst other products, customized module designs and shapes for the roofing market.
- The EU funded Construct-PV aims to develop customizable, efficient and low cost BIPV for opaque surfaces of buildings.

⁴ http://www.enfsolar.com/directory/panel/innovativePanelDesign_pro

3.3. PV Technology Innovation and Cost Reduction

Over the past 10 years the PV industry has demonstrated its capacity drive up efficiency while dramatically reducing costs. Detailed technology roadmaps are in place to guide further developments for all technologies in terms of improved efficiency, reduced costs, increased reliability and economic lifetime and reduced environmental footprint. At EU level there is the European PV Technology Platform Strategic Research Agenda and the SET-Plan Solar Europe Industrial Initiation Implementation Plan 2013-1015. Also the PV sector stakeholders have produced a series of recommendations as part of the new SET-Plan Integrated Roadmap process [4]. Similarly the IEA has included a series of targets in its Solar Photovoltaic Energy Roadmap 2014 [10] – see Table 5.

Table 5: IEA technology recommendations from the IEA.

<i>This roadmap recommends the following actions</i>	<i>Time frames</i>
1. Increase module efficiencies to 40% (HCPV), 24% (sc-Si), 19%(mc-Si; CdTe; CIGS) or 12% (a-Si/ μ c-Si; organic; dye-sensitised).	Complete by 2017.
2. Increase performance ratios and decrease degradation rates.	Complete by 2020.
3. Diversify module specifications for variable environments.	Complete by 2020.
4. Reduce Si consumption to 3 g/W while increasing module longevity. Reduce silver consumption.	Complete by 2020.
5. Enlarge wafer size. Generalise reusable moulds.	Complete by 2020.
6. Develop low-cost high-efficiency high-output bifacial 1-sun tandem cells, and design specific systems around them.	Complete by 2020.
7. Develop specific PV materials for building integration, road integration and other specific supports.	Complete by 2025.
8. Further reduce Si consumption below 2 g/W and increase efficiencies to 50% (HCPV), 28% (tandem cells), 22% (mc-Si, CdTe, CIGS), 16% (a-Si/ μ c-Si; organic; dye-sensitised cells).	Complete by 2025.

Concerning cost reduction, Fig. 7 shows the module price learning curve up to the end of 2013, based on the analysis by Fraunhofer ISE [11]. While there are some indications that the prices for crystalline silicon products stabilized in 2013-2014, Bloomberg New Energy Finance claims that top tier Chinese manufacturers already have module production costs as low as US\$ 0.48/W. Further, they assume a further cost reduction to US\$ 0.33/W by 2020. The main cost savings should come from cheaper polysilicon, thinner wafers with smaller kerf losses and increased efficiency. Some additional cost reduction potential is envisaged for the non-silicon cost components. Similarly, for thin film ambitious cost-cutting plans exist – a recent article⁵ in Photovoltaics International claims that costs for CIGS modules can be reduced from a current level of €0.44/W to €0.24/W. Overall, such estimates provide a welcome confirmation of the potential of PV to become truly cost competitive in the electricity market, but they also illustrate the challenges to becoming a viable manufacturer in this market.

⁵ Ilka Luck, Competitiveness of CIGS technology in the light of recent PV developments, - Part II, Photovoltaics International, Q3, September 2014.

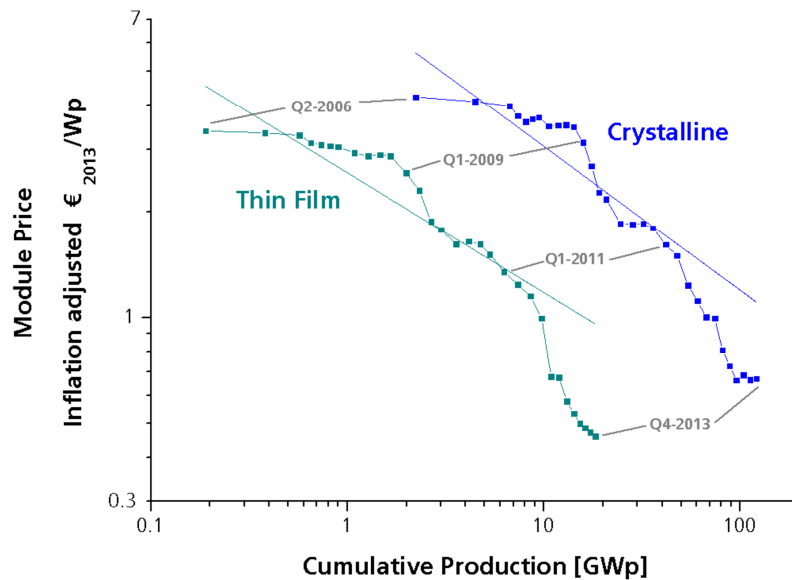


Fig. 7: PV module price learning curve for crystalline silicon and thin film technologies, based on cumulative production up to Q42013 (Fraunhofer Institute for Solar Energy Systems ISE, Photovoltaics Report, Freiburg, 24 October 2014).

3.4. Financing environments move ahead

The financial conditions during the period of the European PV manufacturing contraction were very damaging to the whole sector. While in Europe the financial sector and most banks were impacted by the credit crunch as a result of the financial crisis, Chinese banks had vast financial resources to be invested in order not to be exposed to inflation losses (see Table 6).

During 2013-14 the European financial environment has changed. There is significant credit available now, and the capital cost has also become more favourable. Table 7 shows the diminishing capital costs for market yields of projects with the closest time duration to the PV manufacturing project. There is a general decreasing tendency in Europe, and in the most concerned Member States this capital cost has declined to the fraction of the level of previous year.

An even more significant development in the European financial framework conditions is that renewable energy investment is expected to be one of the beneficiaries of a new infrastructure fund worth €315bn unveiled by the European Commission president Jean-Claude Juncker in late 2014. The new Commission and the European Investment Bank (EIB) could source €63bn of the three-year fund with the rest leveraged from the private sector. An important aspect of this funding is what leverage can be expected from the industry. As the plan calculates with 5/8 fold leverage, the decisive factor is the capacity to provide the substantial private part. As many sectors (i.e. infrastructure) have expressed concerns over their ability to contribute these high shares, the PV industry may be able to gain an advantage if they can stimulate the required private investment.

Table 6: Chinese province funds to PV manufacturers (<http://www.pv-tech.org/>, 2013)

Region	US \$
Ningxia Hui Autonomous Region	48,117,021
Gansu Province	27,811,638
Xinjiang Autonomous Region	16,576,314
Inner Mongolia Autonomous Region	1,185,320,630
Shandong Province	7,156,605
Shaanxi Province	3,097,132
Shanghai	104,254
Anhui Province	194,072
Hubei Province	150,767

Table 7. Secondary market yields of government bonds with a remaining maturity close to ten years. Source: ECB, <https://www.ecb.europa.eu/stats/money/long/html/index.en.html>

Countries	April 2014	April 2015
Euro area		
Belgium	2.16	0.42
Germany	1.46	0.12
Estonia	-	-
Ireland	2.9	0.73
Greece	6.2	12
Spain	3.11	1.31
France	2.03	0.44
Italy	3.23	1.36
Cyprus	6	6
Latvia	2.8	0.42
Lithuania	3.26	0.58
Luxembourg	1.71	0.06
Malta	2.93	1.15
Netherlands	1.85	0.31
Austria	1.77	0.29
Portugal	3.82	1.87
Slovenia	3.52	1.06
Slovakia	2.47	1.18
Finland	1.84	0.27
Non-euro area		
Bulgaria	3.44	2.36
Czech Republic	2	0.26
Denmark	1.57	0.25
Croatia	4.41	3.17
Hungary	5.56	3.28
Poland	4.1	2.37
Romania	5.15	3.25
Sweden	2.06	0.34
United Kingdom	2.3	1.65

4. EXISTING INITIATIVES TO DEVELOP EU PV INDUSTRY

X-Gigawatt: Since 2013 Fraunhofer ISE has been actively prompting the so-called xGWp concept. Its objectives are:

- Establish a Gigawatt-size photovoltaic cell and module factory with next generation technology in Europe, full capacity 2017/2018
- Prove industrial production readiness with a 100 MW demonstration line
- Promote long-term cooperation of leading companies and research institutes

The timelines are: 2014: form the company; 2015: 0,1 GWp demo line; 2018: 1 GWp fab

This project is to be based on beyond state-of-the-art technology:

- Combining advanced Si-based cell with innovative contacting and other technologies in automated, lean production processes in GW-scale
- Achieving high efficiency cells (22 to 25%) at low prices
- Favourable "characteristics" leading to low electricity generation costs
- Significant further cost reduction through continuing innovation

The core members of the consortium include the Fraunhofer Institute for Solar Energy Systems ISE (DE), the National Solar Energy Institute (INES) (FRA) and the Swiss Center for Electronics and Microtechnology CSEM (SUI), as well as several (un-named) European manufacturing companies.

Solliance is a consortium that brings together R&D expertise from ECN, TNO, Holst Centre, Eindhoven University of Technology, imec and Forschungszentrum Jülich. It targets three principal themes: thin film Si, Copper Indium Gallium Selenide (CIGS), Organic PV (OPV). Its research stretches across the entire field, from fundamentals of materials science to sophisticated production technologies. Industries involved include: Smit Ovens, Brabant Development Corporation, Brainport Industries, Roth&Rau B.V., OM&T (Moser Baer subsidiary), VDL/ETG, Umicore, Philips Innovation Services. It is actively searching industrial partners for developing manufacturing capacity.

SOLARROK is a European cooperation format of regional photovoltaic in Germany, Austria, Spain (Navarra), France (Rhône Alps), Slovenia, Lithuania, and the ELAt region (Dutch-Belgium-German cross border region: Eindhoven, Leuven, Aachen). The project is carrying out a 3-year workplan (1.12.2012 - 30.11.2015) to strengthen European innovation-driven PV industry and research.

5. EUROPEAN R&D LANDSCAPE

Europe has traditionally been a leader in R&D on PV across the whole value chain, but there is a fear however that without being driven by significant European industry for manufacturing and product development, this expertise will decline or move into more ambitious regions of the world.

The latest JRC R&D Capacities Report [13] provides data for 2011 (Table 8), although in the meantime the market situation has changed significantly. As shown in Fig. 8, investments are highly concentrated geographically, with Germany, France, Netherlands and Italy accounting for 69% of the total. It is expected that these figures, particularly for corporate R&D, may have decreased significantly with the shake-out in the manufacturing sector, the financial crisis and the overall slow-down in the EU PV market.

It's nonetheless interesting to note that the stakeholder input to the 2014 SET-Plan integrated road-map includes plans for advanced research, industrial research and development and for market update activities totalling €3.24bn over the period 2015 to 2020 i.e. about €540 m annually, a figure comparable to the 2011 total.

Table 8 PV R&D investments in Europe in 2011.

<i>Public funding available through national mechanisms</i>	€364 million
<i>Public funding available at European level*</i>	€39
<i>Corporate R&D Investment</i>	€548
<i>Number of companies identified in the corporate investment sample</i>	236
<i>Number of countries represented in the corporate investment sample</i>	19

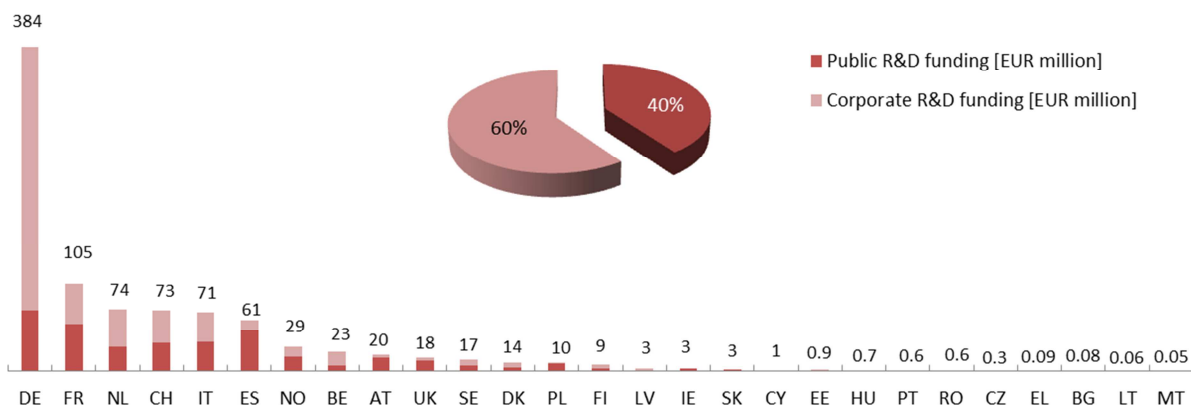


Figure 8: Leading European countries in terms of total R&D investment in solar technologies in 2011. EU funding is excluded. Data sources: IEA, JRC.

To assess the current situation, a "quick-look" bibliometric analysis was made of published research papers over the last 5 years (2010-2014). This used SciVerse Scopus, an online

database owned by Elsevier, as the source⁶. In terms of differentiating technologies, the analysis was confined to "crystalline silicon" and "thin film" categories.

Fig. 9 shows the number of publications annually on a global basis and for the EU-28. This is considered a lagging indicator, i.e. the actual R&D will probably have been done 1 to 2 years before due to the time taken for peer-review and publication process. Also the data would be expected to reflect trends in academic rather than corporate research, since many industrial companies don't publish results in the open literature. Nonetheless several points of interest emerge:

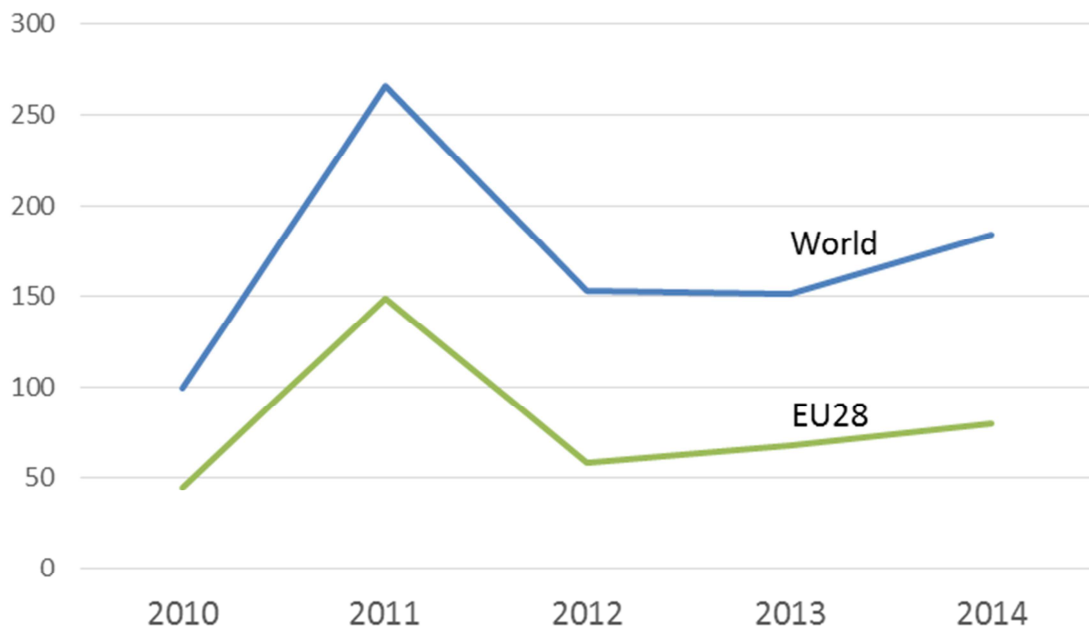
- The absolute number of publications is substantially higher (by a factor of 2 or more) for the thin film category. Independent data for corporate R&D investment paints a very different picture, with c-Si receiving the majority of funds.
- For crystalline silicon materials there is distinct peak in 2011, with the data for 2012/13 coming back to the 2010 level. The papers with EU-based authors contributed between a third and half of all publications, underlining the strength of Europe's scientific base in this field.
- In the thin film category, there appears to be a globally rising trend, but this tendency is weaker for the EU, which has authors involved in approximately 25% of all publications.

The second aspect examined is geographical distribution of the research paper authors. Fig. 10 shows the situation for both crystalline silicon and thin film. Author locations are shown as red points, with the size of the point reflecting the number of papers. The red lines indicate links between co-authors. For crystalline silicon, the three well-known regional centre of excellence are evident: Baden Württemberg and Saxony in Germany and, the Benelux. In contrast for thin film the distribution is much broader, with substantial activity in France, Italy, Spain, Sweden and the UK, in addition to that in the Benelux and Germany.

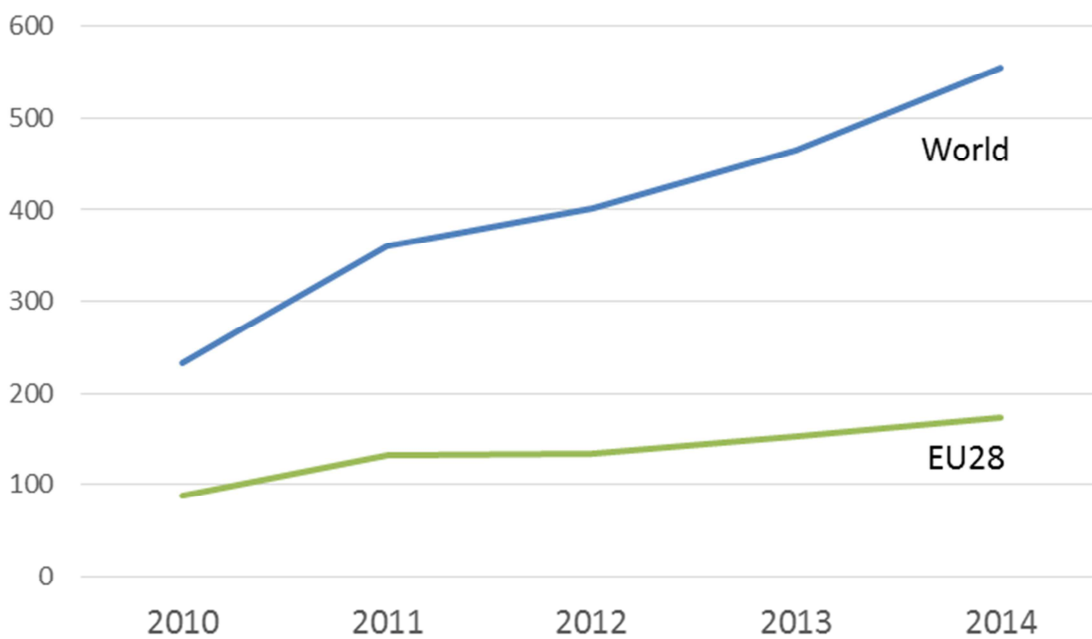
Patent applications: EUROSTAT has data on patent applications to the European Patent Office (EPO) at national level. They also report specifically for energy technologies, and among them, photovoltaic (second technology for patents requests in EU28 in 2010). The most recent complete data is for 2010 (provisional or estimated for 2011-2012). Highlights:

- EU28 countries are responsible of 33 (464) of the total patent applications in Photovoltaic energy in 2010 (1409). Top ranking by country: Japan (26%), US (22%), Germany (15%)
- Worldwide, PV patents represent 20.5% of the total in the classification "technologies or applications for mitigation or adaptation to climate change".
- European countries with more patent application in PV (in order): Germany, France, Italy, Netherlands and UK.

⁶ Publication data is an incomplete indicator of scientific research (although a desirable output). But it is a quantifiable source of data on the production of science. There are other indicators often used to evaluate R&D such as: Gross domestic expenditure on R&D, number of researchers (per million people), country's share of world publications, educational programmes with focus on RE, number of universities/degrees, etc.

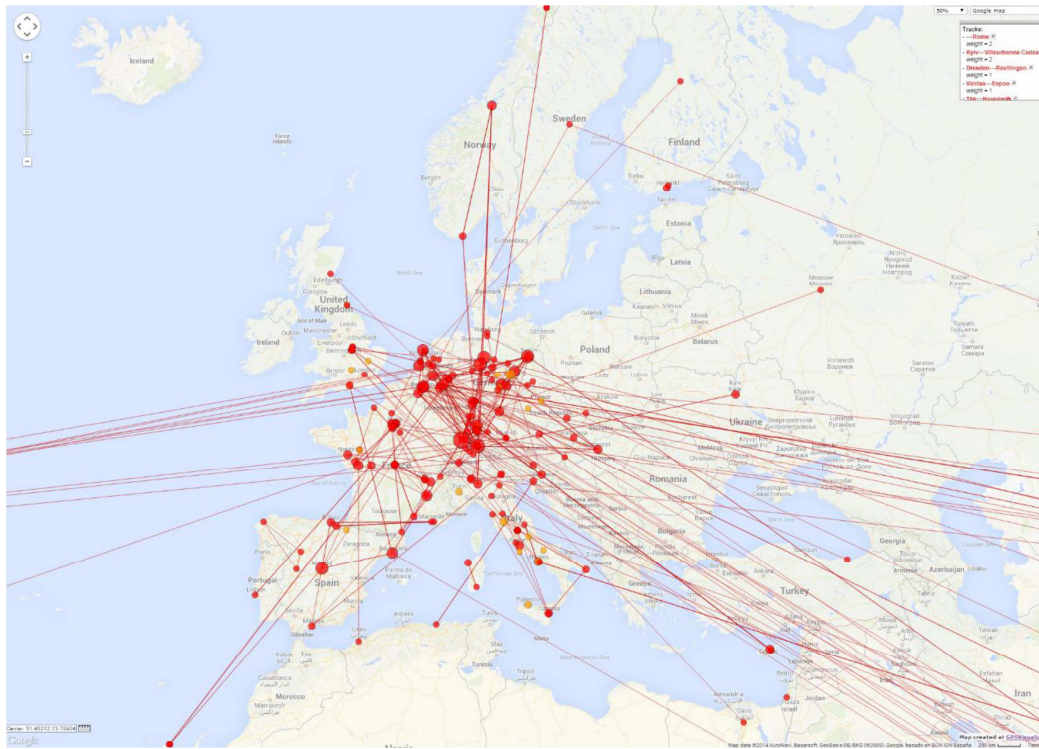


a) Publications on crystalline silicon PV



b) Publications on thin film

Fig. 9: Analysis of published papers in the last 5 years (2010-2014) from the SciVerse Scopus database.



a) Clustering of publications on crystalline silicon PV



b) Clustering of publications on thin film PV

Fig. 10: Geographical distribution of authors of PV research publications from the SciVerse Scopus database. Author locations are shown as red points, with the size of the point reflecting the number of papers. The red lines indicate links between co-authors.

6. SUMMARY & CONCLUSIONS

The global market for photovoltaics, which was dominated by Europe in the last decade, has rapidly changed into one dominated by Asia producers. This internationalisation is mainly due to the rapid growth of PV manufacturers from China and Taiwan, as well as new market entrants from companies located in India, Malaysia, the Philippines, Singapore, South Korea, UAE, etc..

PV manufacturing is transforming into a mass-producing industry with its sights on multi-GW production sites. This development is linked to increasing industry consolidation, which presents a risk and an opportunity at the same time. For small and medium companies to survive the price pressure of the very competitive commodity market, and to compensate for the advantages enjoyed by big companies through the economies of scale that come with large production volumes, they will have to specialise in niche markets offering products with high value added or special solutions tailor-made for customers. The other possibility is to offer technologically more advanced and cheaper solar cell concepts.

The PV market outlook is however bright, with a projected an annual EU market of 6 to 10 GW and a global market of >50 GW. There are potentially huge business opportunities through the value chain for European companies, taking advantage of its still strong R&D base, world-class equipment suppliers as well as the continued presence of several large-scale manufacturers.

Based on the information gathered in this report, it is concluded that for a large-scale manufacturing initiative to be economically viable and to have impact on the global market it would need to aim for a capacity of several GW, with a short-term module cost price target of below EUR 0.40/W. This reflects the reality that product differentiation is based primarily on price, and is expected to continue to be so in the medium term. Furthermore it is essential to involve partners with the expertise to successfully operate GW fabs.

Any initiative seeking substantial support at EU level support would need to involve several European countries and regions and encompass a range of technologies (not just p-type silicon) and innovative product forms.

Finally, while PV electricity is increasingly competitive, it remains a sector driven by policy at both national and EU levels. The size and stable growth potential of the EU "home" market is also important for module manufacturing/assembly location. To change the trend of the currently contracting PV system installation market and enable it to grow again requires a major effort across the EU to ensure a stable investment environment and to reduce soft-costs and administrative barriers.

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Annex 1

Position Paper on the Future of the Photovoltaic Manufacturing Industry in Europe

Prepared by:

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Milan Nitzschke, SolarWorld AG
Ruggero Schleicher-Tappeser, European Gigawatt Fab (xGWp)

27 March 2015

Position Paper on the Future of the Photovoltaic Manufacturing Industry in Europe

1. Background: Current Situation and Outlook for the PV Industry

This document has been prepared by:

Gaëtan Masson	European Photovoltaic Technology Platform
Milan Nitzschke	SolarWorld AG
Ruggero Schleicher-Tappeser	European Gigawatt Fab (xGWp)

20 March 2015

Context and Objectives of the present Position Paper

This position paper proposes concrete policy actions with a view to ensuring that the EU PV industry will play a leading role in making the EU number one in renewable energies as technology producer and not just user of technologies produced elsewhere. The concrete proposals in this document contribute to the implementation of the Energy Union Strategy and could be considered in the development of the forthcoming Renewable Energy Package and of the initiative on EU global technology and innovation leadership on energy and climate to boost growth and jobs. The paper was authored by a group of EU PV industry representatives, at the initiative of the JRC, and as a follow up to the Round Table “Scientific Support to Europe's Photovoltaic Manufacturing Industry” held on 27 January 2015, organised by DG JRC in collaboration with DG ENER and DG GROW.

The Era of PV has Started Globally

With around 40 GW installed in 2014 (compared with 7 GW in 2009, only five years before), the global PV market continues to grow, with China, Japan, the USA taking the lead. Behind these three countries, dozens of markets are growing. In contrast, only around 7 GW have been installed in EU member states in 2014, down from 22 GW in 2011.

Today's PV system price level has reached a certain level of competitiveness in several applications and will become competitive in an increasing number of market segments and countries in the coming years. Long term prospects are even brighter: in September 2014 the International Energy Agency, which has traditionally been conservative on the prospects for renewables, published a PV roadmap until 2050 that envisages that PV could contribute to more than 15% of the world electricity demand. In order to reach such levels, PV markets will have to be multiplied by a factor 5 by 2025. The EU has set the target of 27% renewable energy in 2030, which requires raising the share of renewable electricity from 23% today to at least 45% in 2030¹. Assuming that 40% of the additional capacity would come from PV this requires to install at least 220 GWp² of PV capacity in Europe by 2030.

¹ Staff working document accompanying the Communication of the Commission concerning the Paris protocol (COM(2015)81 final)

² 1 Gigawatt (GW) roughly corresponds to the power of a large conventional (coal or nuclear) power plant. As electricity is generated by PV only when the sun shines, the subscript “peak” is added. Depending on the location, in Europe roughly 7 GWp solar generation capacity is needed to producing

However, at the moment of this historical breakthrough, Europe's PV manufacturing industry has shrunk dramatically, and Europe is at risk of losing the possibility to play a role in the giant PV market of tomorrow.

Larger, Vertically Integrated Actors

Asian and especially Chinese PV companies have succeeded in conquering global markets. One of the main factors was the strong support from Chinese authorities in different forms to build up manufacturing capacities bigger than worldwide demand. Financial resources and economies of scale resulting from this growth together with accelerated vertical integration of major players limit risks and costs. An increasing number of companies combines not only all stages of manufacturing (from wafers to modules), but also the development and construction of power generation systems. Such vertical integration allows for steady revenues, easier access to cheap capital and more continuous utilization of manufacturing capacities.³

Overcapacities are Decreasing Fast with Market Expansion

Massive investment in recent years led to global overcapacities and a fast consolidation of the industry, which was particularly detrimental to small and medium-size European companies that left the business, were acquired or simply disappeared. Meanwhile, the exit of less competitive production lines, as well as continuously growing global markets, have considerably reduced overcapacities, and investment in new capacities has re-started. While overcapacities may not disappear for standard modules, high efficiency high quality modules meet a strong and increasing demand allowing for higher margins. A European strategy should therefore focus on this sector. However, production of photovoltaic devices will probably remain a highly innovative cyclical business just as the chip industry – creating strong players is therefore important.

Crystalline Silicon Dominates

Crystalline silicon is by far the dominant technology after having achieved stronger cost reductions than competing technologies. In order to continue lowering costs, it is expected that several technologies could progress in parallel and get into healthy competition about cell efficiency and costs. EU industry is leading in developing and applying incremental approaches, among them PERC⁴ and similar technologies. Heterojunction⁵ as more radically innovating technology, which requires more new equipment for enabling larger innovation steps, promises fast progress and low costs. Depending on their legacy, major producers adopt different strategies but will all have to invest into research and equipment. A new wave of investments will thoroughly change the PV

the same amount of electricity as 1GW of a nearly continuously running power plant. The production capacities of cell and module factories are measured in MWp or GWp per year (GWp/a). A "Gigawatt Factory" therefore has a yearly output of photovoltaic devices totaling 1 GWp.

³ European PV manufacturers were among the first ones to develop in this direction, but their crisis prevented faster progress.

⁴ PERC (passivated rear-emitter cell) technologies improve the electrical properties of crystalline silicon cell and thereby also the efficiency.

⁵ Heterojunction technology combines crystalline silicon with a thin film of amorphous silicon and allows for cell efficiencies up to 25%.

industry. Europe has the chance to play a role again if it makes smart use of its still existing technological leadership⁶.

Pure thin-film and organic PV technologies may become very important at a later stage. It is important to support their further development.

2. Main Challenges & Strategy for a Competitive PV industry in Europe

Cost Competitive Manufacturing in Europe

While the discussion on creating a level playing field, on capital costs and public support is going on, the evolution of exchange rates is presently playing in favor of Europe. Highly automated factories in Europe, financed at a cost comparable to the one granted to Asian competitors or with a similar level of support as in America, shall be able to deliver competitive PV products.

Maintain a Vibrant Ecosystem for the Entire PV Value Chain in Europe

European research institutes and equipment manufacturers are still global technology leaders. But the loss of their domestic European customer base seriously jeopardizes this position and their financing. If Europe wants to play a role in the future of photovoltaics, one of the main pillars of future energy supply, it needs to maintain a vital ecosystem along the whole value chain including R&D labs, equipment manufacturers and manufacturing companies. Moreover, industrial deployment of PV manufacturing and market presence requires considerable size and capital to be competitive at a global level: Having large players in Europe mastering subsequent technology generations is a precondition for maintaining this ecosystem, investing in new technology generations, re-creating employment in the PV sector, re-conquering a strong position on global markets and ensuring a lasting European capacity in this key technology for the transition to sustainable energy supply systems.

The need for a Coherent European Strategy

While new global PV market leaders from China, Japan, South Korea, Taiwan and the US benefit from official support or the support of large industrial groups, European manufacturers and initiatives are confronted with contradictory public policies, the hostility of large parts of the conventional energy sector and skeptical private investors. Overcoming these obstacles urgently requires a coherent strategy from European institutions and member states combining two dimensions: to guarantee a steadily growing PV market and to support the revitalization of the EU PV industry with a coordinated and focused industry policy.

Support New and Existing Players

This document proposes to focus on a very limited number of strong European players with different strategies, aiming at establishing a next generation PV technology with cell efficiencies⁷ of

⁶ EU Research Framework programme FP7 funds for PV amounted to 7% of the budget for nuclear fission and fusion, and to only about 7% of the budget for non-nuclear energy research. EU researchers and equipment producers have also benefitted from industry research and national budgets and are still able to offer cutting-edge technologies. However with the decline of the European PV industry this may not remain so.

⁷ The percentage of the incoming light which is transformed into electricity by the photovoltaic device.

24% and more, very high quality, high innovation rates, large scale manufacturing and a certain extent of vertical integration for reaching and maintaining a globally competitive position.

Since the global market for very high efficiency cells is still small but rapidly expanding, upgrading and expanding capacities for high efficiency PERC technology and building up new capacities in Europe with a technology based on big-leap innovation such as Heterojunction, might be achieved rapidly without jeopardizing the efforts of existing European manufacturers to compete on global markets with incremental improvements of mature technologies.

A two-fold European strategy capitalizing on both existing industrial capacities and advanced technology potentials should on one hand support existing players in upgrading their production capacities with an incremental innovation approach, and on the other hand to support the creation of a new major European player aiming at a long-term global growth strategy with a direct jump to innovative ultra-high-efficiency technologies, involving more risks. Important Europe-based and globally active potential clients have stated a strong interest in such products at competitive prices. Having European players in the global top five PV manufacturers should be the aim of a coherent European strategy.

3. Main Actions Needed from the Commission and the Member States

Creating Reliable Market Conditions for PV Development in Europe

The European Photovoltaic Industry needs a reliable market outlook for PV in Europe. The confidence of investors in Europe has been compromised by unsteady and contradictory policies: rapid changes in the PV market environment, sudden heavy reductions of feed-in-tariffs, retroactive changes of investment conditions, the hesitation of many member states to allow for even small PV markets, all this resulting in a strong decline of sales in Europe by more than 60% in only 3 years despite falling prices.

Moreover, new regulations in several member states have restricted the possibility to self-consume PV electricity that is considered globally as one of the most promising ways to continue developing the PV market. In that respect, taxes on self-consumption should be prevented. Instead, market design for integrating fluctuating renewables into flexible electricity markets should encourage optimal use of PV electricity generation at all scales, and not oppose it directly or indirectly through inappropriate regulations.

Ensuring a steady market growth for small and large PV systems, for both self-supply and utility use in all EU member states, creating demand for high quality and long-lasting solar systems and obtaining a fair and sustainable market is most important for achieving RE and climate change targets in combination with growing an own strong PV industry. The dramatically reduced cost of PV systems allows us to do this with considerable economic, ecological and employment benefits for the European economies while achieving more energy independence. The European Union should therefore commit to removing existing obstacles and to develop and encourage appropriate mechanisms at different levels. More harmonization and coordination between member states may be useful in a European Energy Union in which PV is one of the main energy supply pillars – however, a certain degree of competition between national and regional systems has accelerated the development of appropriate mechanisms in the last two decades.

In order to cover a consistent share (50%) of a European PV market of 10 to 20 GWp per year with European production, determined efforts are necessary for building a competitive local industry.

Focusing Support on Core Areas

Focusing of efforts on key areas is essential for rapid success. The main danger lies in a loss of manufacturing in Europe for important “Key Enabling Technologies” like PV wafer, cells and modules.

Without a competitive production hub, Europe will also lose its world renowned industrial competence in production machinery, material supply and ultimately its research, development and innovation competence in this area. Moreover, the embedding of photovoltaic devices in energy supply systems is very important and Europe has specific competence in this field. Support should focus on the following fields:

- A. **Upgrading existing crystalline silicon manufacturing capacities at Gigawatt scale** with incremental innovation. Especially PERC and PERL technologies can help to improve cell efficiencies, to maintain technological leadership in the field of the dominating c-Si market segment, and to improve profitability for existing industries.
- B. **Establishing manufacturing facilities at Gigawatt size** with big-leap innovation technology, based on successful demonstration lines. Heterojunction technologies combining crystalline and thin-film silicon are worldwide dominating the efforts for achieving disruptive efficiency improvements. Europe has cutting-edge competencies and equipment in this field.
- C. **Research and demonstration in a wider field of emerging technologies.** CIGS, CPV, Perovskites etc. could become important further down the road and Europe needs to prepare in time, supporting existing actors.
- D. **Smart integration of PV systems in energy systems** can reduce costs and facilitate the handling of fluctuating electricity generation. Different PV technologies offer different opportunities for mechanical and electrical integration. PV manufacturers therefore need to be involved in system design (including storage).

The time window for this unique opportunity is narrow: decisions for large-scale investment must be taken before the end of this year.

Support Mechanisms in a Competitive Environment

The European PV industry is facing heavy competition from other continents where large PV companies have been established with substantial public support. Europe still has cutting edge technologies. However, for living up to their potential, European PV manufacturing companies need targeted support for overcoming initial difficulties linked to the lack of investor confidence and the lack of sufficient size. Reducing risks is essential in this phase. Two kinds of support are therefore most important:

- **Facilitated loans, loan guarantees and risk capital (VC) in order to encourage investors, and enable the industry to invest and reach sufficient scale**
- **Focused public support for research, development and industry-scale demonstration**

PV needs sufficient funds in the support mechanisms for research, development and demonstration. Industry-scale demonstration lines for advanced manufacturing are essential for

transferring research results into business practice. Procedures need to be streamlined in order to avoid loss of time and complex negotiations with co-funding member states.

A special task force should coordinate the opportunities of financial support at European, national and regional levels in order to speed up procedures and negotiations. Moreover, a benchmark analysis on how industrial production in the PV sector is supported in other continents should be carried out as a basis for developing adequate support in Europe.

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