European Commission

Assessment of Photovoltaics (PV)

Final report

Trinomics

Trinomics B.V
April – 2017

EUR 27985 EN

Research and Innovation

EUROPEAN COMMISSION

Directorate-General for Research and Innovation
Directorate G – Energy
Unit G.3 – Renewable Energy Sources

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European Commission
B-1049 Brussels

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Final report

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Directorate-General for Research and Innovation
Assessment of Photovoltaics

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Luxembourg: Publications Office of the European Union, 2017.

PDF ISBN 978-92-79-59749-7 ISSN 1831-9424 doi:10.2777/539983 KI-NA-27985-EN-N

ABSTRACT

This study aims to develop a strategy for rebuilding the European photovoltaic (PV) manufacturing sector, which would be desirable for EU objectives such as economic growth, leadership in renewable energy technologies and security of supply. Europe has lost its strong position in several parts of this industry, and the remaining industry suffers from unfavourable framework conditions. Still, promising opportunities for reindustrialisation exist by deploying a strategy focused on tailored PV products, knowledge-intensive parts of the value chain and the commercialisation of novel technologies. Such a strategy could be implemented by a set of nine measures that target demand, supply, research, development and innovation (RD&I) and trade related aspects. These measures appear to be feasible but require a coordinated effort to be successful. The Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW), Directorate-General for Energy (DG ENER) and Directorate-General for Research and Innovation (DG RTD) would be best positioned to lead the strategy, but would require committed leadership from the industry and the financial sector.

Cette étude vise à développer une stratégie pour la restructuration du secteur européen de la construction photovoltaïque, laquelle serait souhaitable en vue des objectifs européens de croissance économique, de leadership dans les technologies d'énergies renouvelables et de sécurité d'approvisionnement. L'Europe a perdu sa position dominante dans de nombreux secteurs de cette industrie et le reste de l'industrie souffre de conditions générales défavorables. Toutefois, il existe des opportunités prometteuses pour la réindustrialisation, qui se traduiraient par le déploiement d'une stratégie centrée sur des produits PV sur-mesure, davantage d'expertise au sein de la chaine de valeur et la commercialisation de nouvelles technologies. Une telle stratégie pourrait être mise en œuvre à travers un ensemble de neuf mesures qui cibleraient l'offre, la demande, la RD&I ainsi que les aspects liés au commerce. Ces mesures semblent être réalisables mais nécessitent un effort coordonné pour aboutir. La DG GROW, ENER et RTD seraient les mieux placées pour mener cette stratégie, mais elles devraient également pouvoir compter sur le leadership de l'industrie et du secteur financier.

EXECUTIVE SUMMARY

Objectives of the study

This is the final report of the Assessment of Photovoltaics (PV) Study 2015/RTD/SC/PP-03601-2015, carried out for the European Commission, DG Research.[1] The general objectives of the study were to include:

1. 'The assessment of the current situation of the PV sector in Europe and worldwide and a synthesis of the causes of the EU industrial decline on PV manufacturing.'
2. 'The identification of options for a strategy to rebuild the EU PV manufacturing sector and possible priorities, based upon a clear understanding of strengths and weaknesses and considering the various studies recently produced and ongoing on this sector.'

The study focused on the rebuilding of the PV manufacturing sector and proposed recommendations that were specifically geared towards this goal. This final report provides a concise overview of the key findings of the study and focuses extensively on the strategy for rebuilding the sector and the concrete measures and stakeholders involved in its execution.

Background

Solar PV is expected to play an important role in the future energy system. The technology is improving at a rapid pace, and the future deployment rates are expected to grow significantly. Meanwhile, EU manufacturers have lost part of their strong position, especially in wafer, cell and module manufacturing. Rebuilding a strong position in PV manufacturing would be desirable as it contributes to EU objectives such as economic growth, innovativeness and security of supply.

Current position of the EU PV industry

While Europe has lost considerable market share, there is still a significant PV industry at present, with an estimated annual turnover of EUR 5 billion. The remaining industry consists, for a large part, of equipment manufacturers (63 % of EU turnover) and inverter manufacturers (20 % of EU turnover).

The strengths and weaknesses of the European industry can be largely explained by looking at the EU framework conditions. These framework conditions result in relatively high costs for inputs such as labour, energy, materials and equipment that are most important for the mass-production of polysilicon, wafers, cells and modules. The more knowledge-intensive equipment and inverter manufacturing industries are less affected by these framework conditions, and can benefit from a skilled labour force and strong research infrastructure. Meanwhile, the weak local demand, supply chain and lack of a government commitment to rebuilding the industry negatively impact all parts of the industry.

Strategy to rebuild the EU PV industry

Notwithstanding the historical decline of the EU industry and the largely unfavourable framework conditions, we still identify several opportunities for rebuilding the industry. These opportunities have been translated into a differentiation strategy consisting of three pillars.

The aim of the first pillar is to develop a strong position in the market segment for tailored PV products.[2] We conclude that this market segment offers attractive opportunities for reindustrialisation. This is because of the relatively good market prospects compared to competing world regions, the importance of customer proximity and the relative immaturity of the industry worldwide, which does not yet lead to significant supply chain and scale disadvantages. Over time, a strong position in this market segment could lead to significant export opportunities across the world.

The aim of the second pillar is to maintain and, where possible, strengthen the market position of EU equipment and inverter manufacturers.[3] A continued strong position in these industries cannot

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[1] This study is part of the Specific Contract under the Multiple Framework Contract PP-02161-2014: 'Studies in Support to Research and Innovation Policy in the areas of Renewable Energy, Carbon Capture and Storage and Clean Coal.'

[2] Tailored PV products are defined as those products where the customer's buying behaviour is influenced by more than price and expected electricity yield alone, as is the case with building integrated photovoltaics (BIPV) where aesthetics and customisation also influence purchasing decisions.

[3] As well as several smaller segments where Europe retains a strong position, such as anti-reflective coatings.

be taken for granted because of threats such as the lack of local customers (i.e. wafer, cell and module manufacturers) and the efforts of competing regions to gain market share. This pillar of the strategy aims to counter these threats to preserve a leading position in the global PV market.

The aim of the third pillar is for the EU to become a leader in next generation PV technologies. The benefit of next generation technologies is that cost disadvantages resulting from the supply chain and economies of scale are less prominent and may even be reversed if the European industry manages to scale up ahead of competition. In order to do so, a sufficient technological lead in those technologies would need to be established and transferred to the industry successfully. Europe has strong research and labour skills that can be utilised to establish such a technological lead and can benefit from the presence of leading equipment manufacturers.

Implementation measures

A set of nine implementation measures has been proposed. These include measures to boost the demand for tailored PV products, to improve the transparency on product quality and to improve the sales prospects for the European industry in global markets. Furthermore, measures are included to improve access to capital and stimulate cluster formation. Finally, measures are proposed to improve the generation, transfer and protection of knowledge for the benefit of the industry.

The majority of the implementation measures can be implemented within a relatively short time frame (2 to 5 years) and require only limited costs. Hence, we consider the strategy and its accompanying implementation measures relatively feasible to implement, while acknowledging that substantial political willingness and perseverance of the involved stakeholders would be required.

Key stakeholders

The execution of the strategy would require strategic involvement of the remaining large EU PV manufacturers, the financial sector and the leading European research institutions. Furthermore, we propose involving interested companies from related sectors, such as construction, oil and gas and electronics. The public sector should be represented by high-level decision makers from DG GROW, DG ENER and DG RTD as well as their counterparts in the most relevant Member States. Additionally, a broad set of other parties should be involved for the execution of specific implementation measures.

Conclusions

We conclude that rebuilding a strong position in PV manufacturing can contribute to various EU objectives and that there are several opportunities to do so. The strategy and implementation measures that we propose appear to be feasible but require a coordinated effort to be successful. DG GROW, DG ENER and DG RTD would be best positioned to lead the strategy, but would require committed leadership from the industry and financial sector.

RÉSUMÉ

Objectifs de l'étude

Ceci est le rapport final de l'étude 2015/RTD/SC/PP-03601-2015 sur l'évaluation du secteur photovoltaïque (PV), réalisé pour la Commission Européenne, DG Recherche.[4] Les objectifs généraux de l'étude devaient inclure:

1. « L'évaluation de la situation actuelle du secteur photovoltaïque en Europe et dans le monde, ainsi qu'une synthèse des causes du déclin industriel de l'Europe dans le secteur de la construction photovoltaïque. »
2. « L'identification d'options et d'éventuelles priorités en vue d'une stratégie de restructuration du secteur de la construction photovoltaïque, basée sur une compréhension claire de ses forces et faiblesses et prenant en compte les différentes études en cours et récemment sorties sur ce secteur. »

Cette étude est donc centrée sur la restructuration du secteur de la construction photovoltaïque et propose des recommandations spécialement adaptées à cet objectif. Ce rapport final fournit une vision synthétique des principales conclusions de l'étude et se concentre plus particulièrement sur une stratégie de restructuration de ce secteur, sur des mesures concrètes et sur l'identification des acteurs en charge de leur exécution.

Contexte

Le solaire photovoltaïque devrait jouer un rôle important dans le système énergétique futur. Cette technologie se perfectionne rapidement et les futurs taux de déploiement devraient augmenter de manière significative. En attendant, les fabricants européens sont en train de perdre leur position dominante, notamment en ce qui concerne la fabrication de galettes, de cellules et de modules. Restaurer une position dominante dans le secteur de la construction photovoltaïque est souhaitable car cela contribuerait aux objectifs européens de croissance économique, d'innovation et de sécurité d'approvisionnement.

Etat actuel de l'industrie européenne du PV

Bien que l'Europe ait perdu des parts de marché considérables, l'industrie européenne du PV reste tout de même importante, avec un chiffre d'affaire annuel de 5 milliards d'euros. Cette industrie comprend principalement des fabricants d'équipements (63% du chiffre d'affaire européen) et des fabricants d'onduleurs (20% du chiffre d'affaire européen).

Les forces et faiblesses de l'industrie européenne s'expliquent principalement par les conditions d'encadrement de l'UE. Ces conditions d'encadrement ont pour conséquence des coûts relativement élevés en ce qui concerne les apports, tels que la main d'œuvre, l'énergie, les matériaux et les équipements, ce qui impacte la production de masse de polysilicium, de galettes, de cellules et de modules. Les industries de fabrication d'équipements et d'ondulateurs dont la production est marquée par une forte intensité de connaissance sont moins impactées par ces conditions d'encadrement et bénéficient d'une main d'œuvre qualifiée et de bonnes infrastructures de recherche. Toutefois, la faiblesse de la demande locale et de la chaine d'approvisionnement, ainsi que le manque d'engagement gouvernemental quant à la restructuration de cette industrie a un impact négatif sur cette dernière.

Stratégie pour la restructuration de l'industrie européenne du PV

En dépit du déclin de l'industrie européenne et de conditions d'encadrement largement défavorables, nous identifions encore plusieurs opportunités pour la restructuration de l'industrie du PV. Ces opportunités ont été traduites en une stratégie de différentiation qui comporte trois piliers.

Le but du premier pilier est de développer une position solide dans le segment de marché des produits PV sur-mesure.[5] Nous concluons que ce segment de marché offre des opportunités intéressantes pour la réindustrialisation. Cela est dû à des perspectives de marché relativement bonnes comparées à d'autres régions concurrentes, à l'importance de la proximité avec les clients et à la relative immaturité du reste de l'industrie mondiale, ce qui ne mène pas encore à une

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[4] Cette étude est incluse dans le contrat spécifique appartenant au contrat-cadre multiple PP-02161-2014 : « Études visant à soutenir la politique de recherche et d'innovation dans les domaines des énergies renouvelables, de la capture et du stockage du carbone, ainsi que du charbon propre »

[5] Les produits PV sur-mesure sont définis comme des produits pour lesquels le comportement d'achat du consommateur n'est pas seulement influencé par le prix et le rendement électrique, comme pour le BIPV par exemple, pour lesquels l'esthétique et la personnalisation influencent les décisions d'achat.

chaine d'approvisionnement conséquente et à des désavantages d'échelle. Avec le temps, une position forte dans ce segment de marché pourrait mener à d'importantes opportunités d'exportation à travers le monde.

Le but du second pilier est de maintenir, et là où c'est possible, de renforcer la position de marché des fabricants européens d'équipements et d'onduleurs.[6] La pérennité d'une position forte au sein de ces industries ne peut être tenue pour acquise en raison de menaces telles que le manque de clients locaux (par exemple pour les fabricants de galettes, de cellules et de modules) ou des efforts des régions concurrentes pour acquérir des parts de marché. Ce pilier de la stratégie a pour objectif de contrer ces menaces, dans le but de préserver une position dominante dans l'ensemble du marché du PV.

Le but du troisième pilier est de faire de l'Europe un leader dans les technologies photovoltaïques de la prochaine génération. L'avantage de ces technologies est que les désavantages de coûts liés à la chaine d'approvisionnement et aux économies d'échelles sont moins visibles et peuvent même être annulés si l'industrie européenne parvient à devancer la compétition. Pour cela, une avance suffisante dans ces technologies de nouvelle génération devrait être établie et transférée à l'industrie. L'Europe dispose de compétences solides dans le champ de la recherche et de la main d'œuvre, qui peuvent être utilisées pour atteindre cette avance technologique. Elle bénéficie également de la présence de fabricants d'équipements de premier plan sur son territoire.

Mesures d'application

Un ensemble de neuf mesures d'application a été proposé. Il inclut des mesures pour booster la demande de produits PV sur-mesure, pour améliorer la transparence sur la qualité des produits et pour améliorer les perspectives de ventes de l'industrie européenne sur le marché mondial. De plus, des mesures ont été incluses pour améliorer l'accès au capital et pour stimuler la formation de clusters. Enfin, des mesures sont proposées pour améliorer la production, le transfert et la protection de connaissances, au profit de l'industrie.

La majorité des mesures d'application peuvent être mises en œuvre dans une période de temps assez courte (2 à 5 ans) et requièrent des couts limités. Ainsi, nous considérons que la mise en œuvre de la stratégie et de ses mesures d'application est réalisable, tout en reconnaissant que la volonté et la persévérance politique des acteurs impliqués est primordiale.

Acteurs clés

L'exécution de la stratégie nécessiterait l'implication des grands fabricants de PV européens, du secteur financier et des principales institutions de recherche européennes. De plus, nous proposons d'impliquer les entreprises des secteurs connexes comme le secteur de la construction, du pétrole, du gaz et de l'électronique. Le secteur public devrait être représenté par des décideurs de haut niveau provenant de la DG GROW, DG ENER et DG RTD ainsi que par leurs homologues dans les Etats Membres les plus pertinents. Par ailleurs, un large ensemble d'autres acteurs devrait être impliqué dans la mise en œuvre de mesures d'application spécifiques.

Conclusions

Nous concluons que la reconstruction d'une position forte dans le secteur de la construction de PV peut contribuer à divers objectifs de européens et qu'il existe de nombreuses opportunités pour atteindre cet objectif. La stratégie et les mesures d'application que nous proposons semblent être réalisables mais requièrent un effort coordonné pour aboutir. La DG GROW, ENER et RTD seraient les mieux placées pour mener cette stratégie, mais elles devraient également pouvoir compter sur le leadership de l'industrie et du secteur financier.

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[6] Ainsi que quelques autres segments plus restreints pour lesquels l'Europe conserve une forte position, comme les revêtements anti-reflets.

CONTENTS

1. INTRODUCTION

1.1. Objectives of the study

This is the final report of the Assessment of Photovoltaics (PV) Study 2015/RTD/SC/PP-03601-2015, carried out for the European Commission, DG Research.[7] The study was implemented in the period February 2016 – February 2017 by a consortium led by Trinomics and including DNV GL, JIIP, PWC and Ricardo Energy & Environment.

The general objectives of the study were to include:

1. 'The assessment of the current situation of the PV sector in Europe and worldwide and a synthesis of the causes of the EU industrial decline on PV manufacturing'.
2. 'The identification of options for a strategy to rebuild the EU PV manufacturing sector and possible priorities, based upon a clear understanding of strengths and weaknesses and considering the various studies recently produced and ongoing on this sector.'

The study hence focused on rebuilding the PV manufacturing sector and proposed recommendations that were specifically geared towards this goal. Consequently, the study paid less attention to PV services such as installation, operations and maintenance and recycling and to broader issues related to the uptake of PV, such as grid related issues, the role of prosumers or electricity storage.

The study was divided into ten different tasks, which were grouped into three blocks of work:

1. **PV situation assessment** (including Task A: Current state, Task B: Market outlook, and Task C: Historical review of EU decline);
2. **Competitive strategy for European PV industry** (including Task D: Opportunities for European re-industrialisation, Task E: Competitors' strategies and Task F: Strategies to rebuild European PV sector);
3. **Path to a successful strategy implementation** (including Task G: Framework conditions to be improved, Task H: Proposal for implementation measures Task I: Key players for implementation and Task J: R&I instruments to be improved).

The purpose of this final report is to present the findings of the study that are most relevant for initiating the next steps to rebuild the EU PV manufacturing industry. Hence, the focus is on the third block of work: path to a successful strategy implementation. Additionally, the main findings from the first two blocks of work are briefly discussed to provide the underlying logic for the proposed strategy. This report should not be seen as a summary of all the project's findings. The executive summaries of the individual task reports can be used for that purpose.

1.2. Background

Recent developments have shown the importance of solar PV as one of the most promising energy technologies.[8] The global average c-Si module price has fallen from 5 USD/Wp in 2000 to about 0.50 USD/Wp in 2016[9] (see also Figure 1.1) and the end of cost reductions of solar PV is not in sight as a result of further technology improvements in solar PV modules, advances in manufacturing, potential for further economies of scale and reductions in balance of system (BoS) costs, especially for utility-scale PV systems. Forecasts of future worldwide PV deployment have continuously been raised and although current forecasts and scenarios vary significantly they all point to strong growth for the deployment of PV, ranging from a 16 to 40-fold growth in PV installed capacity by 2050. From a geographical perspective, demand becomes more global and shifts to the developing world: in all scenarios, the growth in installed capacity outside Europe is much higher than within Europe. The main growth regions include China, India, other countries in Asia, Africa and the Middle East, signalling that the opportunities for EU PV manufacturers will be increasingly outside Europe.

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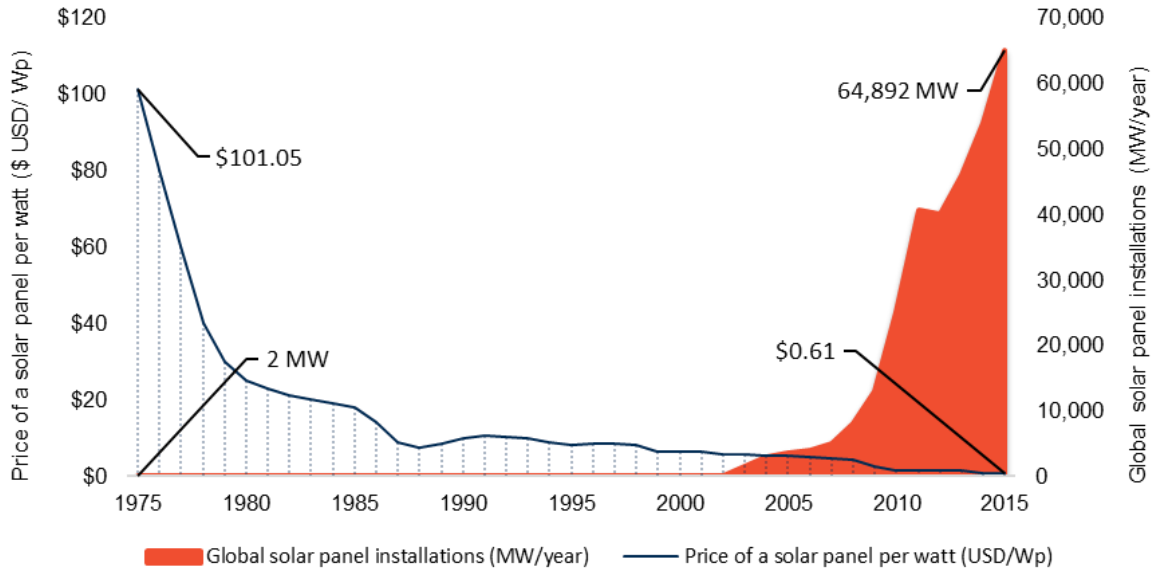
[7] This study is part of the Specific Contract under the Multiple Framework Contract PP-02161-2014: 'Studies in Support to Research and Innovation Policy in the areas of Renewable Energy, Carbon Capture and Storage and Clean Coal.'

[8] The global weighted average solar PV investment cost decreased to 1810 USD/kW in 2015 – only onshore wind is still cheaper with a global weighted average investment cost of 1560 USD/kW (Irena, 2016).

[9] Retrieved April 5, 2017, from https://www.pv-magazine.com/features/investors/module-price-index/

Figure 1.1 Global solar PV deployment and solar PV module price



Source: Own elaboration based on Earth Policy Institute/ Bloomberg (Retrieved April 5, 2017, from http://reneweconomy.com.au/graph-of-the-day-why-solar-power-is-taking-over-the-world-94360/)

Key questions are whether and how the EU PV manufacturing sector would be able to benefit from this expected growth, and how the sector can be further supported in doing this through developing and implementing a European PV support strategy, which is currently lacking.

This should be seen in the context of a PV sector that has changed dramatically over the last ten years. From 2008 onwards, Europe has lost considerable market share in PV cell and module manufacturing, mainly to China, which has developed into a dominant PV player. At the same time, the EU PV industry is still strong in equipment and inverter manufacturing and in project development and installation, and has various leading and world-renowned research institutes on PV on which a strategy to rebuild the EU PV manufacturing sector could be based.

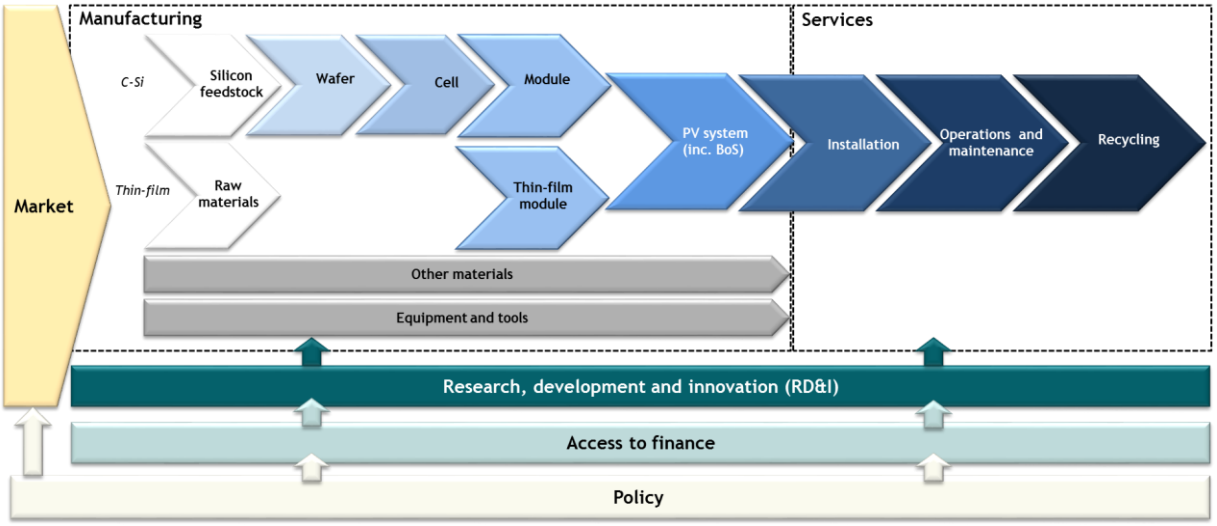
1.3. Sources of information

The analysis in the study is based on desk research of a wide range of policy documents, scenario analyses, academic studies, industry reports, websites of PV companies and PV representative organisations and other information that is publicly available. Each task report contains a list of references of the information sources that were used in that particular task. Also, around 50 interviews and two workshops were held with a variety of stakeholders, including policy makers, sector experts, representatives of knowledge institutes and the PV industry.

1.4. Scope of the study

The scope of this study can be clearly illustrated by looking at the PV value chain shown in Figure 1.2. The parts of the value chain that are of primary interest for this study are included in the 'manufacturing' box in the middle. These are the main manufacturing steps that our proposed strategy aims to rebuild. The downstream services, on the other hand, are not the subject of this study and are only touched upon briefly when relevant for the discussion on the manufacturing steps. Other elements of the value chain such as the market, RD&I and access to finance feature in our discussion on the impact of framework conditions on the competitiveness of the EU manufacturing industry.

Figure 1.2 The extended PV value chain



Source: Task A report.

The manufacturing activities include silicon feedstock, wafer, cell, module and BoS component manufacturing. PV manufacturing is, in essence, the process of transforming light absorbing materials into solar cells, which are then assembled into PV modules. PV manufacturing is characterised by a modular and scalable manufacturing process, a low degree of customisation and a long lifetime of the end product.

The PV production technologies can be widely divided into crystalline silicon (c-Si) wafer based and thin-film based production technologies. The c-Si wafer based PV cells use silicon based semiconductor materials. The polysilicon is shaped into ingots, which are sliced to wafers ready for PV cell production. The PV cells are the basic building block of a PV module, which typically consists of a number of cells assembled in arrays. The thin-film technology is based on the deposition of the semiconducting material directly on a substrate (glass, plastic or metal) and thus the manufacturing process is less complex and costly. However, thin-film based PV modules still have lower efficiency rates when compared to c-Si modules.

A further distinction, made throughout the whole report, is the one between standardised (panels) and tailored PV products. Standardised PV products are made for the mass market, are commoditised in the sense that they are primarily judged by their price to electricity production ratio and are primarily used in utility scale solar farms and on rooftops. Tailored PV products are specifically designed for a particular application and can have other functions apart from electricity production (e.g. building integrated PV (BIPV)).

1.5. Structure of the report

In Chapter 2, we present our assessment of the EU PV sector, with a focus on the manufacturing part of the value chain. We subsequently discuss the reasons for the decline of EU PV manufacturing over the last decade, the current position of the EU PV sector along the value chain and the extent to which EU framework conditions impact the competitive position of EU PV manufacturers.

In Chapter 3 we first discuss the need for a strategy to rebuild PV manufacturing in Europe and what such a strategy should achieve. Subsequently, we discuss various options to realise the objectives of the strategy and present a set of concrete implementation measures to put the strategy in practice. Finally, we identify the key players who should be involved to make the strategy a success.

In Chapter 4 we present our conclusions and the next steps following the release of this document.

2. ASSESSMENT OF THE EU PV SECTOR

2.1. Reasons for the decline of EU PV manufacturing

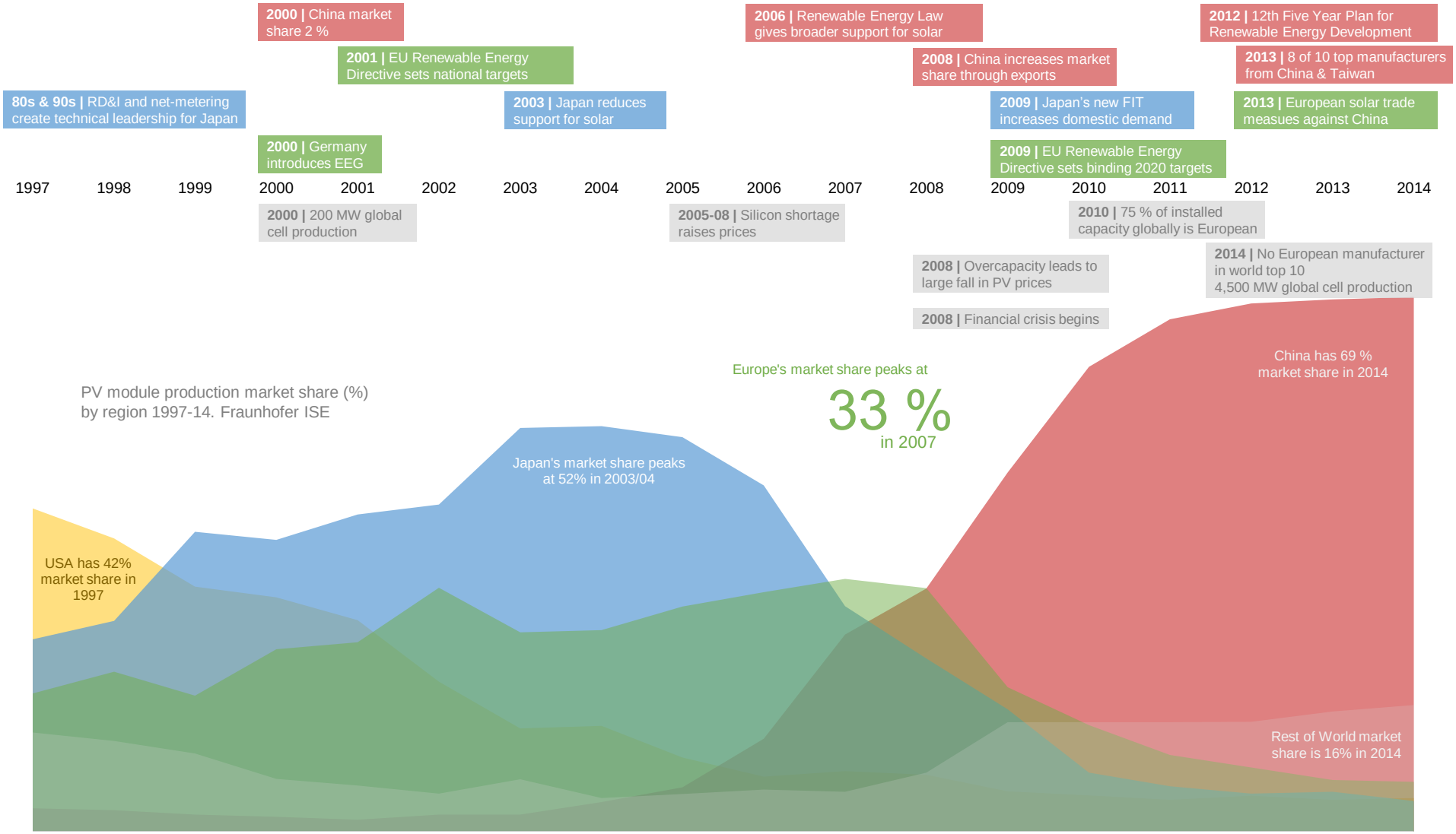
Together with the Unites States of America and Japan, the EU established an early lead in the production of PV modules, which was driven by public investment in demand side and supply side programmes. As can be seen in Figure 2.1, in the mid-2000s European PV module manufacturing held a global production market share of around 30 %. After 2007 European production output continued to increase, but not as fast as global output. Eventually, by 2012, European production started to fall amid continued global growth.

The decline of the European industry is caused by an interplay of factors. The basis was laid between 2004 and 2010 when investments in EU manufacturing capacities were relatively low. Initially, this was caused by the shortage of polysilicon[10] which resulted in higher module prices and slower market growth, which made investors reluctant to finance new plants. Subsequently, the 2008 financial crisis played an important role as it made it very hard for European manufacturers to get access to capital. In the meantime, several European governments introduced feed-in tariffs that dramatically increased the size of the PV market. Due to the low investment levels in new manufacturing capacities, European manufacturers could not fulfil this surge in demand. China, on the other hand, had invested heavily in manufacturing capacities (instead of stimulating demand) which allowed it to fill the gap that was left by the European manufacturers and take an early lead in terms of economies of scale. So with the benefit of hindsight, the EU PV manufacturing sector had paused growth in capacity just before the EU market for solar PV products was about to enter its strongest phase of growth.

What made matters worse for European manufacturers were the take-or-pay contracts for polysilicon that several had entered into. These contracts obliged EU manufacturers to buy polysilicon at a high price after the silicon shortage had disappeared. This put them at a competitive disadvantage versus new Chinese entrants that had invested in their own polysilicon manufacturing capacities. Furthermore, budget cuts and retroactive taxation in a number of European markets reduced the size of traditional markets for European manufacturers and damaged investor confidence. Meanwhile, the Chinese Government continued supporting its industry by providing, for instance, government debt and guarantees. All these factors eventually led to bankruptcies of EU manufacturers and Chinese dominance in wafer, cell and module manufacturing, with current global market shares between 60 and 70 %.

[10] Polysilicon is the main raw material for the ingots and hence the wafers used to make cells and construct modules.

Figure 2.1 Timeline of events that affected the European and global PV market

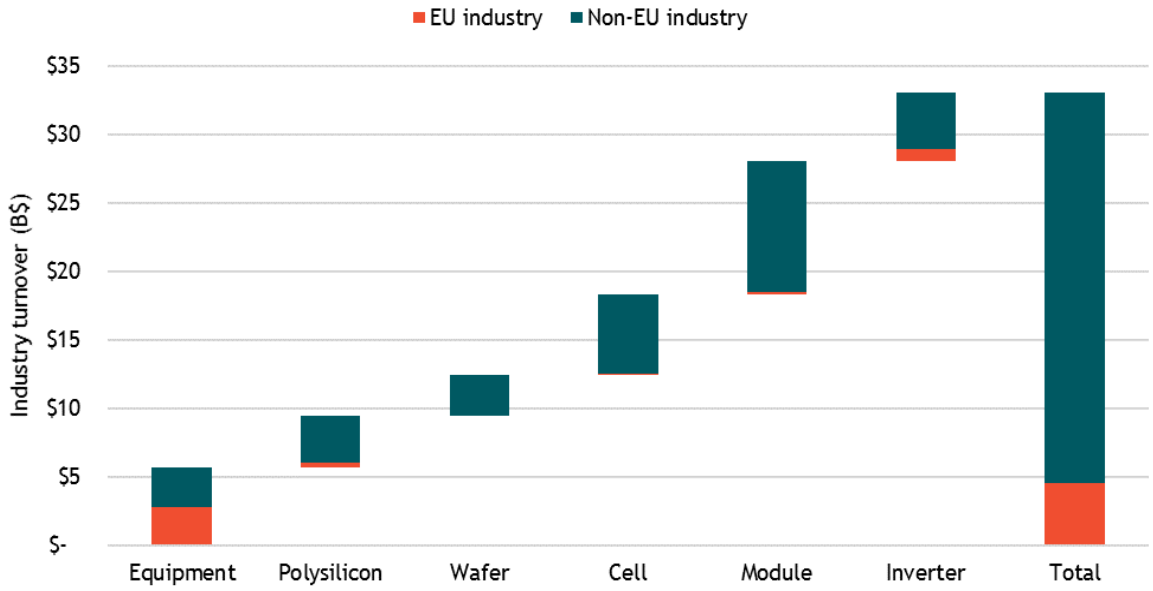


Source: Task C report.

2.2. Current position of the EU PV industry

As shown in Figure 2.2, the relative position of EU manufacturers differs distinctly along the PV value chain.

Figure 2.2 Industry turnover in PV manufacturing per segment of the value chain (2015)



Source: Own elaboration, Task E and Task F report.
Note: The figures per production step exclude the costs of procuring materials/equipment from the previous production step to avoid double counting, but include other procured materials.

EU equipment manufacturers are still leading, with a global market share of around 50 %, while EU inverter manufacturers (in particular global market leader SMA) have a global market share of above 18 %. In silicon manufacturing, Europe's global market share of 11 % is driven by one company (Wacker Chemie) that has managed to remain competitive on the global market. On the other hand, as a result of the developments described in the previous section, Europe plays only a minor role in wafer, cell and module manufacturing (well below 5 % of global demand). Here, SolarWorld is the only significant European player with capacities between 1 and 1.5 GW per manufacturing step. Global thin-film manufacturing is still limited in volume. The main players are US and Japanese firms.

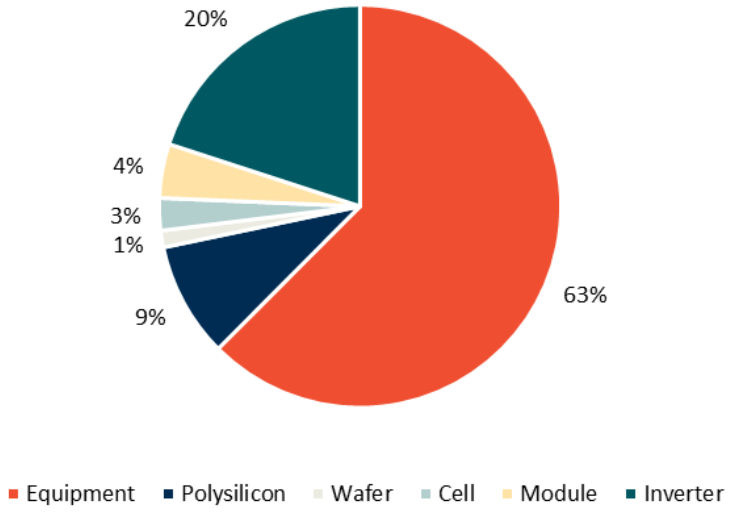
For all parts of the value chain, the international market is more important than the EU market. This holds true for EU silicon, inverter and equipment manufacturers, and EU producers of other materials used in the supply chain. For EU cell and module manufacturers the international market is also of increasing importance.[11]

Total turnover of the EU PV manufacturing industry is estimated to be approximately USD 5 billion, which is ca. 15 % of global turnover.[12] Figure 2-3 below provides an overview of the share of the different manufacturing steps of the total EU industry turnover, confirming that equipment manufacturing and, to a lesser extent, inverter manufacturing are responsible for the bulk of EU PV manufacturing.

[11] For example, approximately 40 % of Solar World's production in the EU is sold outside Europe (direct communication).

[12] Figure for 2015, Task F report.

Figure 2.3 Share of total EU PV industry turnover per manufacturing segment of the value chain (2015)



Source: Own elaboration, Task F report.
Note: The turnover per manufacturing segment of the value chain excludes the costs of procuring materials/equipment from the previous production step to avoid double counting, but includes other procured materials.

2.3. Framework conditions impacting on competitive position

2.3.1. Relevance of framework conditions

Our analysis has demonstrated that the size and composition of the remaining EU PV industry can be explained to a large extent by the framework conditions. Their impact on the competitiveness of PV manufacturers can be summarised into the following three questions that are relevant when deciding upon a potential investment in new PV manufacturing capacities:

- **Cost level:** do the framework conditions allow for manufacturing at a competitive cost level?
- **Differentiation:** do the framework conditions allow for manufacturing in a smarter way and/or allow manufactures to offer specific added value to customers?
- **Committed environment:** do the framework conditions result in a supportive and predictable environment to operate in?

Various framework conditions are relevant to answer these questions. The cost level is, for instance, impacted by the costs for production inputs such as labour, energy and materials. Furthermore, the depreciation of equipment and cost of capital for financing the investments are relevant costs that are impacted by the framework conditions. Finally, government support measures such as subsidies or cheap loans may lead to different cost levels across geographies.

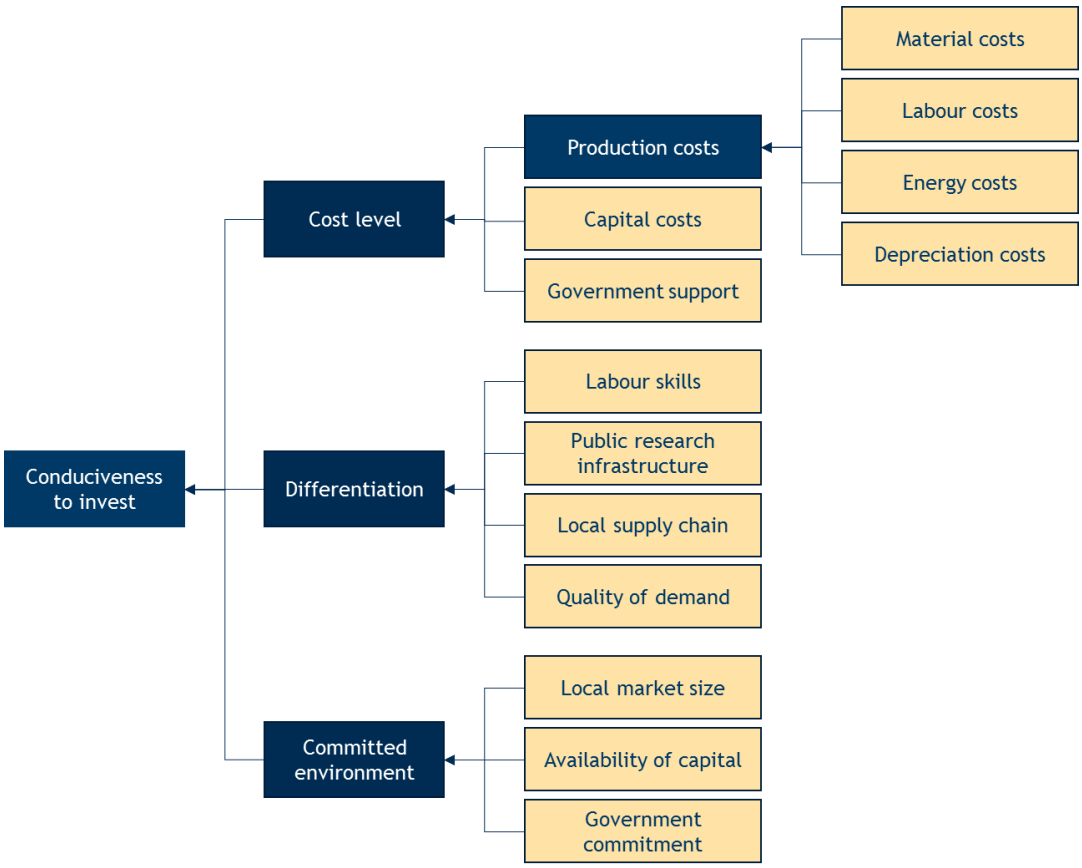
When it comes to the ability to differentiate, other framework conditions are relevant, such as the availability of skilled labour and leading research institutions. Also the presence of strong supply chain partners could be beneficial for a manufacturer's ability to differentiate, as well as a customer base that values differentiated products (quality of demand).

Finally, some framework conditions exist that do not directly impact a manufacturer's cost level or ability to differentiate but can still play a large role in enabling investments in the industry. A large and growing local market is one of those, as well as the availability of the appropriate forms of capital. Furthermore, a government that expresses a clear commitment to the development of the industry is considered of relevance for investment decisions.

An overview of the main framework conditions that we have identified and assessed in the study is presented in Figure 2.4.[13]

[13] In Task G, these framework conditions have been assessed for the most promising EU countries identified in Task D (Germany, France, Italy and Poland) and two main non-EU competitor countries (China and USA).

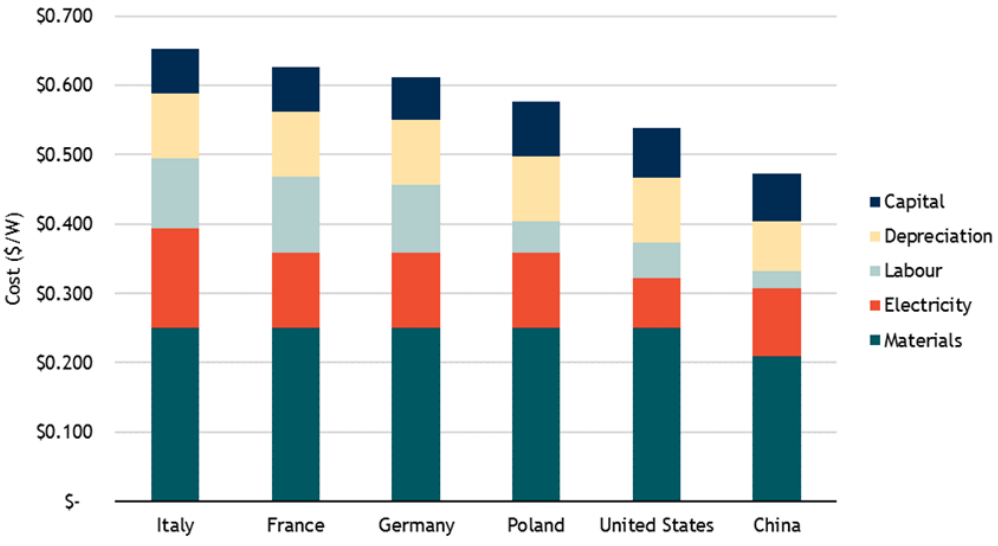
Figure 2.4 Selected framework conditions and their relevance for investments in PV manufacturing capacity



2.3.2. Impact of framework conditions: cost level

The assessment of the six framework conditions that impact the cost level shows that an EU multi-crystalline silicon supply chain faces a significant disadvantage compared to China and the USA. We estimated the cost disadvantage compared to China to range from USD 0.10/W (Poland) to USD 0.18/W (Italy) on a total cost base of USD 0.47/W (for China), which equates to costs that are 20-40 % higher than in China. Also, when compared to the United States, we observe a cost disadvantage, albeit about USD 0.07/W less than compared to China (ca. 6-25 % higher costs in Europe). The reasons for this cost disadvantage can be summarised as relatively high input costs for labour and energy, a less well-developed supply chain that results in higher material and equipment costs (i.e. depreciation) and government interventions. Figure 2.5 shows the breakdown of the costs per framework condition and their cumulative impact.

Figure 2.5 Cost estimates for a multi-crystalline silicon supply chain



Source: Own elaboration, Task G. Cost estimates are based on an analysis of various sources from 2013 - 2016.

These cost disadvantages are not set in stone though, as several drivers of change might alter this assessment in the future. A key driver of change is technological progress: the rapid pace of innovation may lead to obsolescence of current manufacturing equipment and may change the importance of the different cost components. The impact of labour and energy cost disadvantages may, for instance, be alleviated by more energy-efficient or automated processes. Additionally, processes that reduce material losses or the substitution of expensive materials may mitigate the impact of higher material costs. Furthermore, trade restrictions such as import duties could compensate for the impact of Chinese Government support, although these might have negative effects for downstream parts of the value chain.

There are also several uncertainties that could impact Europe's competitive position with respect to the cost level. Examples include material shortages (such as those experienced with polysilicon), the evolution of China's wages and labour productivity, world energy price differentials and changes in the capital markets. Furthermore, transport costs are expected to become more important because the costs of PV products are decreasing over time, while transporting these products is not expected to become cheaper. This may lead to manufacturing closer to the end-customer, especially for modules.

Finally, it should be noted that these cost differences apply to an integrated multi-crystalline silicon supply chain (polysilicon-module) and one needs to be cautious when extrapolating the estimates to other technologies and other parts of the value chain. The key difference with inverter and equipment manufacturing is the large market share of EU manufacturers in these segments, which would probably lead to a smaller supply chain disadvantage, if any. The key difference with thin-film and new PV technologies results from the absence of a mature supply chain. As a result, materials and depreciation cost disadvantages may be less prominent for these technologies, and could even be reversed if Europe manages to scale-up its supply chain ahead of its competitors.

2.3.3. Impact of the framework conditions: differentiation

The framework conditions in Europe are more favourable when it comes to enabling differentiation, especially in terms of labour skills and research infrastructure.

With respect to labour skills we conclude that EU manufacturers can benefit from a competitive advantage. However, the high mobility of specialised labour and the relative ease of re-training factory workers leads to a relatively low importance of this framework condition. An important uncertainty that may impact the competitive advantage is the speed at which China's labour force and education system develops.

The public research infrastructure in the EU also provides a competitive advantage, which we consider of high importance for PV manufacturers. Importantly, we conclude that policy makers can influence this framework condition in various ways, such as through increasing the level of funding and improving the efficiency and effectiveness of allocating these funds. Additionally, improvements can be sought in the process of transferring technology to the local industry.

EU countries face a competitive disadvantage when it comes to the presence of a local supply chain to innovate with. The Chinese supply chain in particular is much better developed. The globalised nature of supply chains, however, makes this framework condition less important for a manufacturer's location decision.

The quality of demand framework condition entails the appreciation of higher quality and/or tailored products by the market. Operating in a market where such differentiation is rewarded could be beneficial for a manufacturer's ability to differentiate. We observe however, that there is currently little room for differentiated solutions in the PV market in general, as most products are sold as commodities with competition determined on the basis of price. Furthermore, we find that a higher quality of demand would not necessarily benefit local manufacturers because these markets could also be served by foreign competitors. Still, a home market which offers more room for differentiated products would be beneficial for manufacturers who seek to compete on the basis of differentiation.

2.3.4. Impact of framework conditions: committed environment

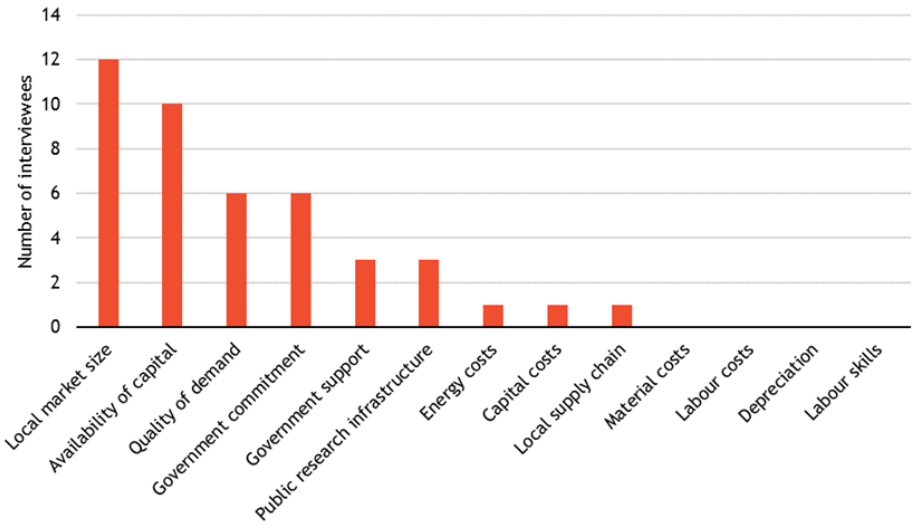
As shown in Figure 2.6, the experts interviewed and also our literature review confirm that a strong local market, the availability of sufficient and fit-for-purpose capital and the articulation of a clear government commitment to rebuilding the PV industry are important factors to stimulate investments.

The current European PV market is, in terms of size and growth, less attractive than the Chinese and US markets. Together with the historical lack of stability in support measures, this has a significant negative impact on the attractiveness of the industry for investors.

Capital availability is raised by various experts as a key framework condition that should be improved. The overall abundance of cheap capital across the world does not necessarily translate to easy financing for the European PV industry, related to the overall lack of profitability and the low investor confidence due to policy instability and bankruptcies in the past. Furthermore, EU start-ups face specific capital barriers to scaling-up, amongst others because of the lack of adequately sized venture capital funds in Europe.

Finally, European governments have not shown a commitment to rebuilding the PV industry, let alone a comprehensive strategy. This contrasts sharply with the situation in the main competing countries, such as China and the United States, which have communicated a concrete ambition to build a strong local PV industry and have developed a (relatively) comprehensive strategy substantiated with measures focusing on RD&I, manufacturing and demand. Recently, however, a number of plans and measures have been announced that may signal a strengthened European commitment to developing the EU PV sector, such as the 2015 Strategic Energy Technology (SET) plan and the proposals communicated as part of the winter package that was announced at the end of 2016.

Figure 2.6 Priority of framework conditions to be improved according to the interviewees[14]



Source: Own elaboration based on interview inputs, Task G.

[14] Responses of 18 interviewees to the question 'Which framework conditions are most crucial to improve in order to stimulate the European solar PV manufacturing industry?' Interviewees could select up to three framework conditions.

3. A STRATEGY TO REBUILD EU PV MANUFACTURING CAPACITIES

3.1. What is the problem?

Solar PV is one of the most promising renewable energy technologies, and all forecasts point to a strong growth in global PV deployment in the coming decades. A strong position of the EU in PV manufacturing would be desirable for various reasons, as it can contribute to:

1. **Economic growth**: the global PV manufacturing industry has an annual turnover of more than USD 30 billion, of which the EU industry captures ca. USD 5 billion.[15] Given the growth prospects of solar PV, this value can increase considerably.

2. **Leadership in low-carbon technologies**: a strong position in the innovative PV manufacturing sector would facilitate the EU's ambition to support breakthroughs in low-carbon and clean energy technologies, as outlined in the Energy Union strategy.

3. **Independence/security of supply**: EU PV manufacturing capacities in strategic parts of the value chain would safeguard technology independence and security of supply for the future energy system, which will depend more on PV. EU companies should not necessarily be present in the entire value chain at all times, but the capabilities that allow for re-establishing the entire value chain should be preserved for when this is required as a result of changing geopolitical or market conditions.

As discussed in the previous chapter, a large part of EU PV manufacturing capacity in wafers, cells and modules has been lost. Insofar as this is related to the adverse framework conditions and resulting cost disadvantages, this is not necessarily a problem from an economic point of view as most of the added value is in other parts of the value chain. The downstream services segments, which are largely a local business, already capture 70 % of the added value and employment in the value chain. Furthermore, the margins in the remaining strongholds of the EU industry (equipment and inverter manufacturing) are higher than in the lost wafer, cell and module manufacturing segments. What is important, however, is that Europe retains the capability to rebuild the full value chain in case of long-term supply disruptions and to be able to commercialise innovative technologies in the European and global markets. In this respect, it is important also to have a strong PV research base, which can only be maintained if there is a strong EU PV manufacturing industry in at least some segments of the value chain.

So far, an encompassing European strategy to rebuild EU PV manufacturing capacities is lacking. Apart from the risk of missing interesting growth opportunities, the threat is that the current strongholds such as equipment and inverter manufacturing[16] will lose ground to the growing international competition and that this will ultimately weaken the EU PV research base and consequently the ability to realise the goals with respect to independence/security of supply and leadership in low-carbon technologies.

3.2. What should be achieved?

The final goal is a strong EU PV manufacturing industry contributing to economic growth, innovation and energy independence, leveraging on the relative strengths of the EU and technological opportunities that fit these strengths best. This can, in our view, be best achieved through pursuing a differentiation strategy focusing on **(1) tailored PV products**, **(2) the current strongholds in the PV value chain** and **(3) the development and commercialisation of novel technologies**, rather than a strategy trying to regain market share in wafer, cell and module manufacturing for the mass market based on cost-competition or market protection (this is explained in more detail in Section 3.3).

The aim of the **first pillar** of the strategy is to develop a strong position in the market segment for tailored PV products. Tailored PV products are defined as those products where the customer's buying behaviour is influenced by more than price and expected electricity yield alone, as is the case with BIPV, for example, where aesthetics and customisation also influence purchasing decisions. We consider that this market segment offers attractive opportunities for reindustrialisation in Europe. This is driven by relatively good market prospects compared to competing world regions, the importance of customer proximity and the relative immaturity of the

[15] Task F report.

[16] Further areas where Europe still has a strong position are anti-reflective coatings and connectors, among others.

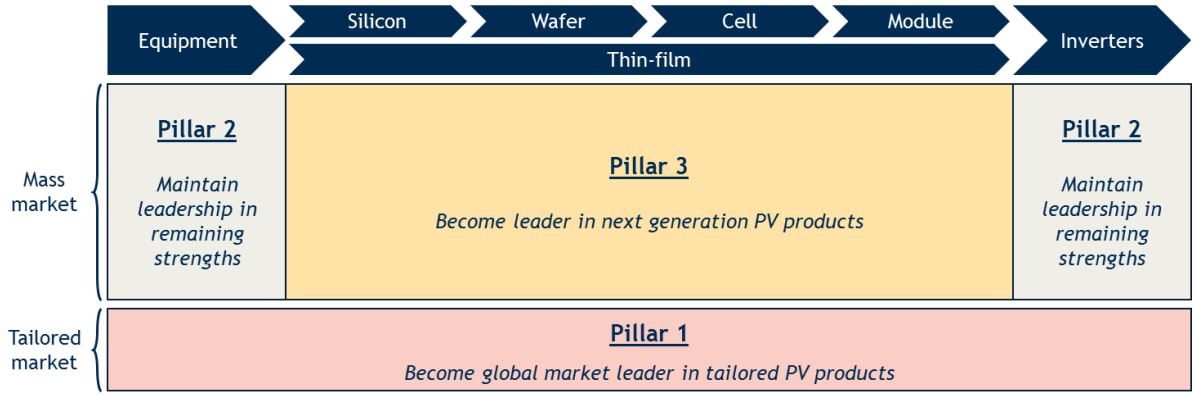
industry worldwide, which does not yet lead to significant supply chain and scale disadvantages. Furthermore, the demand in this segment fits well with the traditional European strengths of high quality and customised product manufacturing. The main impact of this pillar would be on manufacturers of tailored PV products, such as thin-film manufacturers. The impact on other parts of the value chain would be less prominent but also positive. Broader benefits from this pillar of the strategy are expected in terms of additional progress to climate targets and increased employment in the maintenance and installation sector. The challenges reported by EU manufacturers in this market segment consist of a lack of capital and insufficient demand. These issues are more realistic to overcome than supply chain and scale disadvantages that the mass market for standard PV panels faces.

The aim of the **second pillar** is to maintain and, where possible, strengthen the market position of EU equipment and inverter manufacturers.[17] Equipment and inverter manufacturing for the mass market provides possibilities to increase EU based manufacturing, particularly when the global growth of the PV sector accelerates. The knowledge-intensive nature of production fits well with the European research and labour skills strengths, which explains the current strong position in the global market. However, there are various threats that may impact this position, such as the lack of local customers (i.e. wafer, cell and module manufacturers) and the efforts of competing regions to gain market share. This pillar of the strategy would aim to counter these threats to preserve a leading position in the global PV market. The positive impact of this pillar is predominantly on equipment and inverter manufacturing; the impact on other parts of the value chain and the broader benefits are limited.

The aim of the **third pillar** is to become a leader in next generation PV technologies. The benefit of new technologies is that the PV manufacturing facilities and parts of the supply chain do not exist yet. Hence, EU manufacturers would not face a cost disadvantage resulting from the supply chain and economies of scale and may even create an advantage of their own, if they manage to scale up ahead of competition. In order to do so, a sufficient technological lead in those technologies would need to be established and transferred to the industry successfully. Europe has strong research and labour skills that can be utilised to establish such a technological lead and can benefit from local equipment manufacturers that are still leading in several domains. This pillar aims to utilise these strengths to rebuild the European industry once a next generation technology can be commercialised. The impact of this pillar would mainly be felt in the core of the value chain (wafer->module, thin-film). If successful, the impact could be large. The main issue with this pillar of the strategy results from the high uncertainties involved in RD&I and technology transfer to the industry, which make it the riskiest part of the strategy.

Overall this leads to a strategy that consists of three pillars focusing on different parts of the PV manufacturing value chain and different market segments (see Figure 3.1 below).

Figure 3.1 Focal areas in terms of value chain and market segment of each pillar of the strategy



Source: Own elaboration.

3.3. What are the options to achieve the objectives?

3.3.1. Stimulate the demand for PV products (demand-side measures)

Several stakeholders stressed the need to stimulate the EU market for PV products and proposed measures such as increasing renewable energy source (RES) deployment targets.[18] Although a

[17] As well as several smaller segments where Europe retains a strong position, such as anti-reflective coatings.

[18] Task G report.

substantial part of the increased demand for RES would be fulfilled by RES other than PV, and the fact that foreign competitors would also benefit from higher PV demand, we would welcome higher RES deployment targets. This would strengthen the position of EU PV manufacturers to a certain extent and also signal a strengthened commitment for developing RES, including PV, in the EU. For by and large the same reasons, we would also welcome other measures that could support an increased demand for RES, such as resolving grid-connection issues and supporting enabling technologies such as storage and demand response. However, as these measures do not directly improve the competitiveness of EU manufacturers on the global market and also benefit foreign competitors, we have not included them in the proposed implementation measures.

A more direct attempt to boost EU PV manufacturing is to stimulate the overall EU demand for PV products through generic subsidies. Given the relatively weak competitive position of the EU cell and module manufacturers, and the lack of success with such a strategy in the past, we do not recommend this course of action because it could be rather costly and would not result in major increases in industrial activity in Europe.[19]

On the other hand, we clearly see the need to stimulate the demand for tailored PV products to develop a strong position on this market segment through product development, up-scaling of production capacities and cost-improvements. The benefit of stimulating this market is that it is little developed across the world, which offers opportunities to take an early lead that can be used to establish a leading position globally. Furthermore, stimulating this market is expected to have larger benefits for EU manufacturers than stimulating the mass market, because successfully marketing tailored products requires a good understanding of the local customer preferences which EU manufacturers are more likely to have.

3.3.2. Reduce the cost level (supply-side measures)

With regard to the cost level, the analysis of the framework conditions revealed that this is higher for EU PV manufacturers than for Chinese and US manufacturers and that this difference is highest and most important for wafer, cell and module manufacturing. We do not recommend to focus on improving these conditions directly, however, as this would involve high costs and could easily conflict with state aid rules. For example, labour and energy costs are largely driven by market forces and economy wide regulations, which would be difficult to alter for PV manufacturers specifically. Also, material and depreciation costs disadvantages primarily result from the more advanced supply chain in China, which would require large capital investments to replicate.[20]

Still, some focused measures such as providing energy cost discounts to small and medium-sized enterprises (SMEs) or regional support to cluster formation may be considered, as long as this is compatible with state aid rules. Furthermore, we recommend to tackle the specific issue for European SME PV manufacturers to attract capital, which results from a mix of factors, including the lack of appropriately sized venture capital funds, the lack of investor confidence and the risk averseness of the European public funds, including those managed by the European Investment Bank (EIB).

3.3.3. Protect the local market / promote exporting to foreign markets (trade related measures)

Market protection measures such as minimum import prices and import duties are already in place in Europe and aim to protect the European manufacturers from unfair competition from China. However, such measures do not contribute to strengthening the position of EU manufacturers in the main growth markets, which are outside the EU. Hence, we recommend supporting such measures only in very selective cases.

A different approach to protecting EU manufacturers from foreign competition would be to implement local content requirements. However, recent attempts to do so, for instance in India, have demonstrated that the legality would be an issue.[21] Hence, we do not consider this a feasible option and would not recommend supporting it as it may distract attention from more feasible options that are presented in this report.

An alternative angle is to promote the export opportunities for EU PV manufacturers. Such an approach could build upon the remaining strengths in the EU value chain and would recognise that the future PV markets are increasingly outside of Europe. Hence, we do recommend developing a trade initiative.

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[19] See Section 2.1 and Task C report.

[20] See Task G report for a more elaborate discussion.

[21] See Task E report for more details.

3.3.4. Stimulate technological progress (RD&I measures)

Instead of relying on attempts to reduce the overall costs for EU manufacturers or protecting the home market, we recommend focussing on stimulating technological progress to allow EU manufacturers to mitigate or compensate for the cost disadvantages. This approach would be attractive because it can leverage on European strengths in terms of labour skills and research infrastructure. Furthermore, we see potential to improve the RD&I activities in the EU through improving the efficiency and effectiveness of allocating R&D funds (amongst others with sufficient targeting to areas that support the three pillars of the strategy) and strengthening the technology transfer to the industry.

3.3.5. Strengthen government commitment

In addition to the concrete options described above, several stakeholders also stressed the need for a stronger government commitment to rebuilding the EU PV industry. A clear articulation of such a commitment could spur initiatives for reindustrialisation and aid investor confidence. Hence, the adoption of the strategy outlined in this document would in itself be a clear and welcome signal of increased commitment to support the development of the EU PV sector.

Additionally, some specific measures (deployment targets) have been proposed to underpin this government commitment. While we acknowledge the negative impact of historical fluctuations in demand due to changes in support schemes and (retroactive) changes in support measures on investor confidence and the PV sector at large, the cost reductions of PV products make their deployment increasingly economical, irrespective of the availability of support measures.

3.4. Proposed implementation measures

3.4.1. Description of implementation measures

Based on the considerations of the previous section, we propose to implement the strategy through nine types of measures, grouped into demand, supply, RD&I and trade related measures. As shown in Table 3.1, these implementation measures impact on one or more of the pillars of the strategy.

Table 3.1 Proposed implementation measures and their relevance for the pillars of the strategy

Type	Measure	Pillars of the strategy		
		1. Tailored products	2. Remaining strengths	3. Next generation technologies
Demand	Building obligations	✓	S	
	Public procurement	✓	S	
	Standardisation of BIPV products	✓	S	
	Panel and inverter labelling		S	✓
Supply	Access to capital for SMEs	✓	S	✓
	Cluster formation	S	✓	S
RD&I	Public research funding	✓	✓	✓
	Knowledge protection and transfer	S	S	✓
Trade	International cooperation	S	✓	S

Note: Measures are indicated with a '✓' if they are important to one of the pillars of the strategy. Measures that could be supportive to the success of the pillars are indicated with an 'S'.

Building obligations

This measure entails the implementation of an obligation for buildings to produce electricity on-site by using renewable energy technologies. We propose to apply this measure initially on public buildings, new buildings and large scale renovations in the private sector. This measure builds on the Renewable Energy Directive and Energy Performance of Buildings Directive and would require efforts to translate the guidance of these directives into law at Member State level. This should lead to an increased demand for PV products in the built environment, part of which would be fulfilled by tailored products that are targeted with the first pillar of the strategy. As such, it would help to create a market for the European manufacturers of tailored PV products, which is an important condition for the success of pillar 1 of the strategy.

Public procurement

This measure aims to use the major role of public authorities as consumers (19 % of EU GDP) to stimulate the uptake of tailored PV products. It consists of establishing additional green public procurement criteria for building types that are currently not covered and raising the ambition level for the RES uptake in public buildings. This would contribute to the success of pillar 1 of the strategy by growing the market for tailored PV products.

Standardisation of BIPV products

A barrier to the large-scale uptake of BIPV solutions stems from the dual role that BIPV solutions fulfil (building material and electricity generation) which results in the need to comply with both electrical and building standards. This measure aims to tackle this issue by launching an EU level standardisation project to develop a clear regulatory framework that BIPV products should comply with. This framework should specify functional requirements (e.g. fire resistance) but not the technical means and solutions to achieve those requirements as this could hinder innovation and make the market more accessible to foreign mass-producers. Together with the two measures discussed above, this measure would increase the demand for tailored PV products, which is of primary relevance for pillar 1 of the strategy.

Panel and inverter labelling

Consumers are often not aware of how PV products perform over time and, consequently, it is difficult for them to make an informed choice between PV products. As a result, purchasing decisions are often made on the basis of the information that is available (price per capacity (EUR/W)) and disregard lifetime performance (EUR/kWh). This is detrimental to manufacturers of products that differentiate on lifetime performance as well as for consumers who make suboptimal purchasing decisions. This measure aims to overcome this issue by setting an EU-wide comparative label for standard panels and inverters under the Energy Labelling Directive. This would be an informative measure that allows consumers to compare and contrast different products in the market to help them make an informed decision. This should drive demand towards better quality products, hereby creating a launching market for manufacturers of next generation technologies (pillar 3 of the strategy) that are competitive in such a market.

Access to capital for SMEs

The first part of this measure is to appoint dedicated consulting services in the most relevant Member States to assist entrepreneurs in attracting finance and to identify any gaps in the financing options available. Subsequently, solutions such as state guarantees and public investment funds are put in place to fill these gaps. This measure should lead to increased investments in EU PV manufacturing capacities, especially for SMEs. This would be most relevant for pillar 1 and pillar 3 of the strategy where we expect a relatively large share of SMEs compared to pillar 2 which targets equipment and inverter manufacturers that are often already past the SME stage.

Cluster formation

This measure aims to re-establish a number of PV clusters to enhance knowledge exchange, labour availability and supply chain strength to the benefit of the organisations involved. Establishing these clusters would require setting up a cluster organisation and devising a cluster policy that includes concrete measures to support the manufacturers and research institutions involved. This measure could build on existing cluster initiatives or start new initiatives where sufficient local support and industrial activity is available. This measure is included primarily to create an attractive environment for the equipment and inverter manufacturers targeted by pillar 2 of the strategy to counter the threat of these manufacturers relocating closer to their main markets outside of Europe.

Public research funding

This measure aims to optimise the contribution of public research funding to the objective of rebuilding the EU PV manufacturing industry. It starts with implementing a periodic review cycle in which the most relevant research topics for rebuilding the industry are identified. Subsequently, EU and Member State research funds are allocated accordingly and the coordination of the research activities at the different levels is improved to avoid overlaps and duplication of funding. Furthermore, the continuity between research and innovation policies is improved to better support the commercialisation of research outcomes. A potential way to organise this is by implementing a challenge-based funding instrument that supports the most promising innovations throughout the full innovation cycle. This measure is very relevant for pillars 2 and 3 of the strategy because the targeted manufacturers rely on a leading knowledge position for their global competitiveness. The

relevance for pillar 1 is more on contributing to the market growth for tailored PV solutions by driving cost reductions.

Knowledge protection and transfer

This measure aims to ensure that publicly funded research results benefit EU manufacturers. We propose a measure similar to an existing provision in the United States which requires owners of publicly funded research results to grant priority access to local manufacturers (also known as domestic preference). Such a provision would be of primary relevance for pillar three of the strategy which requires that next generation technologies are effectively and solely transferred to EU manufacturers to create a competitive advantage.

International cooperation

This measure aims to improve the relationships with key emerging markets to support the globally active European manufacturers in their efforts to sell overseas. The concrete actions would be to use trade agreements, international dialogues and trade missions to favour the sales prospects of the manufacturers targeted by the strategy. In particular, the equipment manufacturers targeted with pillar 2 of the strategy would benefit from this measure for countries that want to build their own cell and module manufacturing capacities.

3.4.2. Assessment of implementation measures

The nine proposed implementation measures have different characteristics in terms of the timeframe and costs of implementation, as well as the expected benefits. Table 3-2 provides a summary of the main characteristics per measure.

Table 3.2 Assessment of proposed implementation measures – summary overview

Type	Measure	Timeframe	Costs	Benefits for the EU industry	Broader benefits
Demand	Building obligations	Short/mid-term	Admin + legislative changes (EUR 1 million – EUR 5 million)	Increased sales opportunities for tailored PV products	Increased employment in installation, maintenance and construction sectors, CO_2 emission reductions
	Public procurement	Short/mid-term	Admin + legislative changes (EUR 1 million – EUR 5 million)		
	BIPV standardisation	Mid-term	Admin + legislative changes (EUR 1 million – EUR 5 million)		
	Panel and inverter labelling	Mid-term	Admin + legislative changes (EUR 1 million – EUR 5 million)	Launching market for high-performance PV products	Better transparency for consumers, enhanced innovation in PV
Supply	Access to capital for SMEs	Short/mid-term	Admin + (potential) financial support (>EUR 5 million)	Improved access to capital for scaling up	N/A
	Cluster formation	Short/mid-term	Admin + (potential) financial support (>EUR 5 million)	Increased productivity, innovativeness and entrepreneurship	Increased employment in related industries and the research sector
RD&I	Public research funding	Short/mid-term	Administrative costs only (<EUR 1 million)	More relevant public research results	N/A
	Knowledge protection & transfer	Long-term	Admin + legislative changes (EUR 1 million – EUR 5 million)	Preferential access to knowledge	N/A
Trade	International cooperation	Short/mid-term	Administrative costs only (<EUR 1 million)	Better sales opportunities in emerging markets	N/A

Source: Own elaboration based on Task H report.

Note: Short-term: 0-2 years, mid-term: 2-5 years, long-term: >5 years for the measure to be implemented. N/A: not applicable.

The timeframe for implementing the measures depends largely on the need for legislative changes, which generally takes relatively long. Especially for measures which require significant legislative changes, such as the knowledge protection and transfer measure, we expect this to result in a relatively long timeframe for the measure to become effective (>5 years). Fortunately, most measures require only modest legislative changes, if any. Hence, we expect it to be feasible for all other measures to become effective within 5 years and for some parts of the measures to be effective within 2 years already.

We estimate that the costs for implementing the public research funding and international cooperation measures are less than EUR 1 million each as they only include administrative costs. Five other measures require some legislative changes which we estimate to result in costs ranging from EUR 1 to EUR 5 million. Only for the supply-side measures (capital for SMEs and cluster formation) do we envision costs that could become higher than EUR 5 million. Overall, we conclude that the costs for implementing the strategy are relatively low compared to the potential size of the industry that they aim to rebuild (global industry size: EUR 5 billion).

The measures result in a range of benefits for the industry that includes increased sales opportunities, better capital availability and more relevant and accessible public research outputs. Furthermore, they contribute to several broader benefits, such as CO_2 emission reductions and increased employment in related sectors.

Overall, the set of measures looks relatively feasible to implement. Still, substantial political willingness and perseverance, as well as a strong collaboration between all involved stakeholders would be required for a successful implementation.

3.5. Who should be involved?

3.5.1. Key players to be involved at strategic level

For the success of the strategy it is important that the right high-level decision makers endorse the strategy and are prepared to allocate resources to its implementation. This would require the involvement of the remaining large PV manufacturers, a selection of banks (public and private) and venture capitalists, which would together be able to develop and fund new manufacturing capacities. Additionally, we suggest involving interested companies from related sectors such as construction, oil and gas and electronics because of their access to capital and ability to remove barriers to the uptake of PV. Furthermore, the leading European research institutions should be involved to facilitate focusing research efforts around the strategy's objectives.

The public sector's involvement would be needed at both EU and Member State level. At EU level the strategic players are DG GROW, DG ENER and DG RTD. Together they are able to influence the policies that will partly determine the success of the strategy, such as building regulations, research funding, knowledge protection and public procurement. At Member State level we recommend including high-level decision makers of those Member States that still have a strong position in one or several manufacturing segments of the value chain and/or research. This would result in the inclusion of a select group of Member States, consisting of countries like Germany, France, Poland, Italy, the Netherlands and Spain.

3.5.2. Key players to be involved at implementation level

The key players for the implementation of the strategy are a broader set of stakeholders. Additional players that would be involved are SMEs in PV manufacturing, regional investment funds, industry associations and joint research programmes, amongst others. Furthermore, DG Trade and its counterparts at Member State level would play a role, as well as regional policy makers. These players could all contribute to the execution of the strategy by offering political support, capital, funding or knowledge.

Table 3-3 provides on overview of the main players that should, in our view, be involved in the execution of the strategy to rebuild EU PV manufacturing capacities.[22]

[22] See the Task I report for further details.

Table 3.3 Overview of key players to be involved in implementing the strategy

Player	Strategic involvement	Building obligations	Public procurement	BIPV standardisation	Panel and inverter labelling	Access to capital for SMEs	Cluster formation	Public research funding	Knowledge protection and transfer	International cooperation
Industry										
EU PV champions	■						■			
EU PV SMEs										
Construction and related sectors										
Finance										
Private banks and funds	■					■	■			
European Investment Bank	■					■				
National public banks/funds						■	■			
Research										
Research institutions	■						■			
Policy – EU level										
DG GROW	■		■	■					■	
DG RTD	■							■		
DG ENER	■	■			■					
DG TRADE										
Policy – Member State (MS)/regional level										
MS/regional 'GROW' policy officers						■	■			
MS/regional 'RTD' policy officers								■		
MS/regional 'ENER' policy officers		■								
MS/regional 'TRADE' policy officers										■

Source: Task I report.
Legend: Orange boxes indicate a major role; yellow boxes indicate a minor role.
Note: Players with no strategic involvement and only a limited role in the implementation measures have been excluded from this overview.

This overview demonstrates that the involvement of the PV manufacturing industry is not only key at the strategic level but also for the execution of most of the implementation measures. Furthermore, the construction sector should be involved, both at strategic level and in three implementation measures.

The financial sector's involvement is required for the measures on capital for SMEs and cluster formation. Furthermore, they fulfil a strategic role in providing capital to the PV industry at large, which justifies their involvement at the strategic level.

The research sector is also identified as a key player for cluster formation initiatives and would be supportive for other measures. As noted earlier, the research sector's involvement should at least involve the five main EU PV research centres. Furthermore, other research institutions in regions selected for cluster formation would be involved.

On the policy side the main message is that DG GROW and its counterparts at Member State level should be heavily involved and would need to take a leading role in both strategic level discussions and several implementation measures. This would require involving the Member States with the biggest potential for rebuilding a PV sector early on. Additionally, DG ENER, DG RTD and their Member State level counterparts would be key players to drive the required policy changes. For the demand side measures, this could span all Member States. However, for the RD&I measures this could be focused on only the most relevant ones. DG TRADE and its Member State level counterparts would have a more limited role and are therefore not proposed to be included on the strategic level.

4. CONCLUSIONS

Rebuilding a strong position in PV manufacturing can contribute to various EU objectives

All projections point to a large role for PV in the future energy system, which will result in a significant growth of the global PV manufacturing industry. If the EU manages to build a strong position in this industry, the benefits will not only include economic growth but also increased energy independence and leadership in innovative energy technologies. As such, it would clearly contribute to the goals set in the Energy Union strategy.

Opportunities to increase the position of EU PV manufacturing exist

Even though the EU industry has lost considerable market share in the past decade, there are opportunities for rebuilding the industry. These opportunities exist in parts of the value chain and market segments where differentiation plays a relatively large role, such as equipment and inverter manufacturing and tailored PV products, such as BIPV. Furthermore, the commercialisation of novel PV technologies could offer opportunities to rebuild the industry. The strong knowledge position of the EU research institutions, skilled labour force and remaining industry players offer a sufficiently strong basis for such a strategy to succeed.

The implementation measures to execute the strategy appear to be feasible

The implementation measures that are proposed to put the strategy in practice do not require large budget increases, and most can be implemented in the short to medium term. Notwithstanding the political willingness and perseverance that are required to implement the measures, we conclude that the overall package seems feasible.

Coordinated action is required for the strategy to succeed

While most implementation measures would be beneficial in isolation, their effectiveness would increase considerably if they are executed in parallel. As a diverse group of stakeholders are required for the execution of the nine measures, it would be important to have a strong central coordination of the actions of all players involved.

DG GROW, DG ENER and DG RTD would be best positioned to lead the strategy

Based on our analysis, we conclude that it would be best if EU level policy makers would drive the strategy. Ideally this would be a collaborative effort of DG GROW, DG ENER and DG RTD, which are able to provide political support to the majority of the strategy's measures. The involvement of Member States would then be tailored to the specifics of the respective countries. The characteristics of the industry, research institutions and market in the different Member States would determine whether it makes sense for them to contribute to the whole strategy, specific pillars of the strategy, or not at all.

Committed leadership of the industry and financial sector is essential

As the success of the overall strategy eventually depends on the willingness of the industry and financial sector to invest in PV manufacturing capacities, the commitment of their leadership is essential. A critical mass of industry champions and leading financial sector players should be involved early on and voice a clear intent to invest if the policy measures are taken. We recommend involving individual companies rather than their industry associations to ensure the people who would eventually decide on investment proposals are on board.

KI-NA-27-985-EN-N

doi: 10.2777/539983
ISBN 978-92-79-59749-7