THE SOLAR EUROPE INDUSTRY INITIATIVE: RESEARCH, TECHNOLOGY DEVELOPMENT AND DEMONSTRATION IN SUPPORT OF 2020 AND LONG-TERM TARGETS

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ABSTRACT

The European Union has set an ambitious target for the implementation of renewable energy technologies by 2020, i.e. a share of 20% of the total energy consumption. In support of these targets the Strategic Energy Technology (SET) Plan has been initiated by the European Commission. One of the key components of this plan is the establishment of Industry Initiatives aiming at technology development and demonstration to enable large-scale deployment at minimum cost and maximum benefits for society. The Solar Europe Industry Initiative (SEII), covering both photovoltaic solar energy and concentrating solar power has been launched in June 2010. It provides clear, technology-related targets and priorities for research, development and demonstration, for EU as well as member state programs. The PV-part of the SEII is a joint effort of the European Photovoltaic Technology Platform and the European Photovoltaic Industry Association, which together represent most of the R&D and industry capacity in Europe.

BACKGROUND AND CONTEXT

The Solar Europe Industry Initiative (SEII) synthesizes a collective effort of the European PV community, involving leading representatives from the industry, from the research community and from the European and national PV associations represented through the European Photovoltaic Industry Association (EPIA) and the European Photovoltaic Technology Platform (EUPVTP).

This paper summarizes the European PV sector strategy and the immediate actions to be taken in the period 2010-2012 to realize the PV solar energy goals for 2020 and beyond, as described in the European Commission PV Roadmap [1], the EUPVTP's Strategic Research Agenda [2] and its Implementation Plan [3] and related documents, as a contribution to the overall targets of the EU. Implementation of the PV sector strategy is necessary for the European PV industry to remain competitive in a global market where an increasing number of new companies and countries become active and where up-scaling of manufacturing and deployment volumes are an essential ingredient of success.

Availability of low-cost, high quality PV technology, wherever it is produced, is a prerequisite for any ambitious deployment scenario. However, the European PV sector has the responsibility and the ambition to maintain a strong position on the global market and to derive economic benefit for the EU taxpayer, who has nursed PV technology through the expensive, initial stages of its development. In response to this situation, and as input for the SET-Plan and EU 2020 targets, the European industry, organized through EPIA, developed a Vision [4] to establish PV as a mainstream clean, sustainable and competitive energy technology providing up to 12% of the European electricity demand by 2020, up to 20% in 2030 and 30% in 2050. Realizing this Vision requires that the right policy framework conditions are set by the EU Member States, and that continuous public support is provided to the industry in order to carry out the research, development and demonstration (RD&D) measures needed. The Solar Europe Industry Initiative describes the strategic RD&D components of "SET For 2020", which are essential to enable rapid, large-scale deployment of PV at minimum cost and maximum benefit for society. Besides the efforts of the PV sector, the success of other Industry Initiatives under the SET-Plan (e.g. the Electricity Grid Initiative) as well as the development of other technologies (electricity storage, electric vehicles, demand side management, etc.) are essential for the success of the SEII. A 12% contribution is only possible if costs are substantially reduced (through innovation, experience and economies of volume), grid integration issues can be solved, and PV markets are strongly and sustainably developed throughout Europe. The SEII describes crucial actions to accelerate cost reduction as well as to provide solutions for high penetration of PV in electricity grids and for integration in the built environment, see Figure 1.

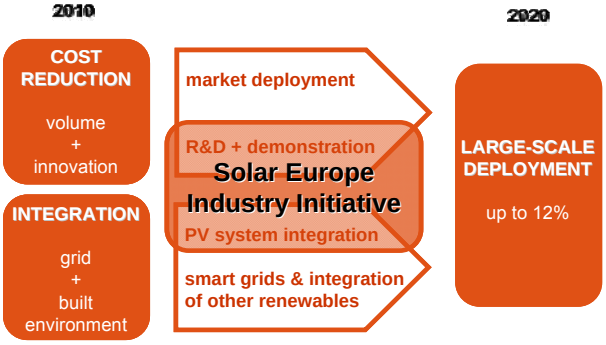

Figure 1. Scope of the Solar Europe Industry Initiative.

STATE OF THE ART AND 2020 OBJECTIVES

For over 30 years the PV industry has demonstrated its capability to achieve fast price reduction, as evidenced by Figure 2, which shows that the price of PV modules has been reduced by ≈20% for each doubling of the cumulative production. The same is roughly true on the system level (note that PV systems consist of modules and the so-called Balance of System (BoS), which comprises electronics and safety devices, cabling, mounting structures, installation, etc.). The rapid decrease of turn-key system prices has been enabled by the combination of innovation (the result of RD&D) and experience combined with economies of scale (the result of market development).

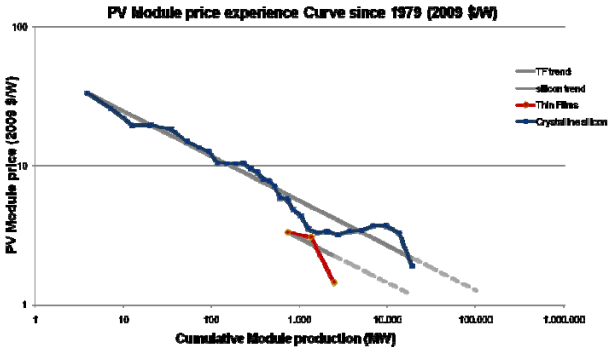

Figure 2. Price-experience curve for photovoltaic modules (courtesy EPIA, 2009).

Clearly, RD&D (the topic of this SEII) by itself will not lead to large scale deployment and to reaching any volume target. The latter is dependent on important other conditions to be met, in particular in the form of market incentives until self-sustained markets are created by continued cost and price reductions. It is stressed, however, that intensified RD&D is crucial to enable PV deployment at the rate and at the rapidly decreasing price levels outlined in "SET for 2020". In other words, the SEII enables such large scale deployment at minimum cost and maximum benefit. In fact, the societal cost benefits that may be reached by choosing an optimum combination of deployment ambition and RD&D efforts easily outweighs the cost of the latter, which is another argument to adopt this SEII.

Although costs and prices of modules and complete systems are important indicators of the evolution of the technology, the most relevant parameter and actually the one which serves to compare PV electricity with other sources of energy is the Levelized Cost of Electricity (LCoE) per kWh generated. Depending on the location, the annual output (proportional to the annual irradiation) varies from 700-800 kWh/kWp in the Scandinavian countries to more than 1500 kWh/kWp in the South of Spain and Italy, Greece and Turkey.

Table I summarizes selected performance indicators for past and state-of-the-art PV components and systems in Southern Europe (assuming a system performance ratio of 0.8), as well as indicative targets for 2015 and 2020 (please note the Table footnotes).

		2007	2010	2015	2020
Turn-key price larger systems (€/Wp)*		≥5	2,5-3,5	2	1,5
PV electricity generation cost in Southern EU (€/kWh)**		0.30 – 0.60	0.13 – 0.25	0.10 – 0.20	0.07 – 0.14
Typical PV module efficiency range (%)	Crystalline silicon	13 - 18%	15 - 20%	16 - 21%	18 - 23%
	Thin films	5 - 11%	6 - 12%	8 - 14%	10 - 16%
	Concentrators	20%	20 - 25%	25 - 30%	30 - 35%
Inverter lifetime (years)		10	15	20	>25
Module lifetime (years)		20 - 25	20 - 25	25 - 30	35 - 40
Energy pay-back time (years)***		2 - 3	1 - 2	1	0.5
Cost of PV + small-scale storage (€/kWh) in Southern EU (grid-connected)****		--	0.35	0.22	<0.15

** System price depends on technology and market maturity*
*** LCoE varies with financing cost and location. Insolation range considered here 1500 - 2000 kWh/m² per year*
**** Best values*
***** Estimated figures based on EUROBAT roadmaps*

Table 1. Indicative targets of the Solar Europe Industry Initiative.

SEII STRUCTURE AND PRIORITY AREAS

The Solar Europe Industry Initiative is based on the idea of "Creating an energy revolution through accelerated evolution" and moving beyond a business-as-usual scenario. Based on an intensive exchange of views and ideas which were worked out in a close collaboration between EPIA and the European Photovoltaic Technology Platform, involving stakeholders from the whole PV industry (cell & module manufacturers, Balance of System suppliers), the research community (universities, research centers), PV-related industries (glass, plastics & encapsulants, raw materials, metals) and, last but not least, equipment suppliers, two major initiatives have been defined:

- SEII 1: Cost reduction
- SEII 2: System integration

Following the R&D activities in the two sub-initiatives, demonstration projects will be carried out to assure a large and successful implementation of the results. The SEII also recognizes the need to develop a program for education & training in Europe, to enable world-class innovation and to avoid a shortage of qualified PV professionals. Activities should address the specific needs of the industry as well as those of the research and development sector and include scientists, engineers, installers, technicians, etc.. The same principle applies for raising awareness & communication activities. The

environmental, social, economical and technical benefits of PV need to be disseminated to the wider public, national and European policy-makers, utilities, architects, construction sector and other important stakeholders. These two areas (i.e. education & training and raising awareness & communication), however, are beyond the scope of Industrial Initiatives and should be covered by parallel actions, see Figure 3.

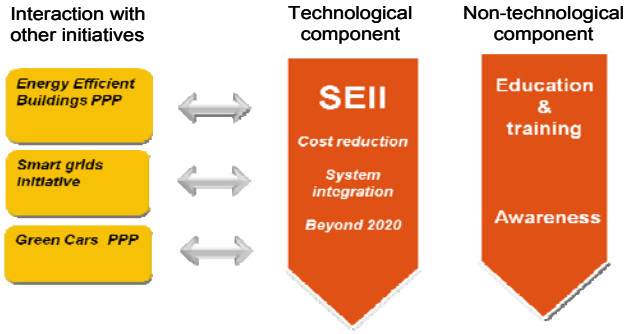

Figure 3. Interaction of the SEII with other initiatives, as well as related actions.

SEII 2: System integration

As distributed PV and other renewable energy technologies mature, they can provide a significant share of European electricity demand. However, as their market share grows, concerns about potential impacts on the stability and operation of the electricity grid may create barriers to their future expansion. In addition, low cost, high-quality integration of PV in buildings and other objects poses major development challenges. The goal of this part of the initiative is to unlock the potential for making PV a mainstream energy source, requiring special focus to be placed on system integration aspects. In order to achieve the target of generating up to 12% of the European electricity consumption by 2020, the PV industry, together with the network operators and building sector, needs to develop economical and technical solutions which will allow a large penetration of PV at a competitive level. The implementation of this part of the initiative will bring benefits to the PV industry, utilities and regulators. On one hand, the production cost of components like inverters and batteries will decrease whereas the lifetime of those devices will increase making PV systems more economically attractive. On the other hand, grid operation will benefit from the ancillary services (frequency stability, voltage control, reactive power) that PV can bring into the system, as well as the reliability of supply when offering PV systems with energy storage solutions. Communication and control functionalities will be developed, tested and implemented facilitating the overall function of energy management systems.

Demonstration projects

The results of the activities implemented under the priority areas “Cost reduction” and “System integration” will be demonstrated under real conditions. The collaboration with other key stakeholders such as utilities, car manufactures and regulators on the one hand and the building industry on the other is also essential at this level. A variety of tests and demonstrations are required to understand the effect of a high penetration of PV systems on the grid. Especially important are the subjects of PV grid integration, PV building integration and interaction with other energy sources (such as wind power and other variable electricity production technologies). The implementation of this part of the initiative will demonstrate the real value of PV technology and electricity, the potential to interact with other energy sources and the added value to network operators and the building sector.

FOCUS OF THE SEII 2010-2012: SELECTED PRIORITY AREAS

To allow a concrete start of the SEII, a tentative set of priority areas has been defined, based on input provided by the industry and research sectors. Member States as well as the European Union are now encouraged to “adopt” those areas which fit best their own strengths and priorities.

The following tables summarize the priority areas (project clusters) for the two main focus areas of the SEII as well as a component aimed at the period beyond 2020.

Cost reduction: paving the way to 2020	
Research theme	**Summary description and project clusters**
Advanced manufacturing processes for cells and modules	This cluster of projects aims at bringing a selection of key commercial technologies (in particular wafer Si, thin-film Si, CIGS and concentrator PV) further towards full maturity, i.e. very large-scale production at the required low cost. It will enable the European PV industry to compete successfully in the global market, to reach grid parity with retail prices (or beyond) in most of Europe and to supply the required hardware for multi-gigawatt-scale deployment of PV.
Performance enhancement and lifetime extension	In addition to the performance optimization and cost reduction on cell and module levels mentioned in the previous cluster, enhancement of the performance *on a system level* and enhancement of the technical lifetime of system components and

	systems are other ways to reduce the generation costs of solar electricity. This cluster of projects aims at increased specific energy output (kWh/Wp•yr) and enhanced lifetime. In addition, the cluster includes projects on very high efficiency approaches beyond industry capability indicated in the previous block.
Materials development & sustainability	To further improve the already favourable environmental profile of PV systems, the energy input for manufacturing and installation needs to be reduced and alternatives for some critical (non earth-abundant or hazardous) elements and materials need to be developed. Both aspects are also clearly related to cost reduction. Moreover, the implementation of the end-of-life module collection and recycling system developed by the PV CYCLE association is addressed. .

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Large-scale PV power plants	Technologies with a high potential but a limited track record, like concentrator PV and advanced thin-film technologies, are hampered in their application because risk assessment cannot be based on field experience. This, in turn, makes it difficult to reach the scale required for cost reduction. This circle may be broken by the development of a few very large (~20 – 40 MWp) PV power plants aimed at demonstrating the feasibility and reliability of the respective technologies. Analyzing the impact of such large PV plants on the grid operability and stability will also support the establishment and construction of a very robust European “smart grid”.

Solar resources, monitoring and simulation	What can we expect and what do we actually get? These are two key questions in relation to large-scale deployment of PV. Projects in this cluster aim at creating accurate & reliable, readily available, and practically useful information on all aspects of PV planning and use, for various stakeholder groups in all EU member states.

Preparing for cost and penetration beyond 2020 levels	
Ultra low cost technologies	In addition to the technologies commercially available today, a range of "emerging" technologies is under development or in the pilot production phase. Prominent examples are the organic solar cells and modules (for example polymer) and CIGS technologies (for instance based on non-vacuum deposition). The general feature that these emerging technologies have in common is that they have potential for very low production costs and new applications. Although advanced versions of commercially available technologies can meet the cost targets for 2020, emerging technologies are an essential part of the R&D portfolio for the next few years because they may bring PV further down in cost on the longer term and because their development towards application maturity requires many years. This cluster comprises projects on emerging technologies which aim (ultimately) at demonstration on a pilot production level. • Research, development and pilot line demonstration of "emerging" technologies (in particular non-vacuum/printed organic and inorganic options) • Development and implementation of dedicated characterisation & testing models and methods, including the required hardware; accelerated lifetime tests
Very high efficiency approaches	In addition to the commercial and emerging technologies mentioned in previous paragraphs, a wide range of "novel" device and conversion concepts are in the laboratory phase. The common feature of these novel approaches is that they aim at efficiencies far beyond the levels foreseen for commercial and emerging technologies. Another common feature is that it is too early to make useful statements about their (future) cost. This cluster aims at exploring the limits of photovoltaic conversion: a strategic activity which is vital for the position of the PV industry sector on the longer term as well as for Europe's global position in the PV field. The USA, Japan, Australia and other countries invest heavily in similar R&D efforts. The aim of the projects in this cluster is to demonstrate the feasibility and added value of the approaches on a device level. • Research and development of novel, PV conversion concepts aiming at very high efficiencies (various applications of quantum dots and other nanostructures, intermediate band semi-conductors, hot-carrier devices, spectrum converters, and more); demonstration on proof-of-concept and/or proof-of-feasibility level • Modelling and characterisation of new concepts and innovative materials using advanced theoretical and experimental methods
Integration concepts for very high levels of PV penetration	As in the case of cell and module technologies, also the concepts and technologies for integration have to evolve and improve over time in order to comply with rapid, large-scale deployment. To prepare for *very* high levels of penetration of PV in the grid as well as in the built environment, this project cluster aims at developing and demonstrating new integration

	concepts (beyond those developed in "Grid and building integration"). • Power and energy management strategies for very high degrees of PV penetration (beyond anticipated 2020 levels), including development and testing of the required hardware, and field tests.

To monitor progress of the SEII, a set of Key Performance Indicators (KPI's) has been developed in the framework of SETIS (Strategic Energy Technology Information System). These KPI's relate to reference PV systems and reference PV manufacturing technologies, but also to specific technical parameters on component or system level.

FINANCING

Although at the start the SEII only has a very limited dedicated budget, it is expected that this will grow over time as existing and new programs are aligned according to the common targets and priorities. The total budget required to carry out the SEII for the period 2010-2020 is estimated to be 9 billion Euros. This amount consists of public (EU and Member States) and private contributions, both in the form of grants and loans, depending on the nature and risk profile of the projects involved. Public contributions vary from less than 30% to 90%, depending on the project type. On average, for the project clusters that may start in first 3 years of the SEII, the public contribution is approximately 43%. A detailed overview of project clusters and their expected financing is beyond the scope of this paper.

CONCLUSION

The Solar Europe Industry Initiative has been designed to become the most important vehicle for collaborative PV RD&D in Europe. It aims to enable PV to make important contributions to the renewable electricity targets for 2020 and beyond and to support the European PV sector to continue to play an important role in manufacturing and deployment of PV technology. The SEII is a joint effort of the majority of EU Member States, the European Commission and the private sector. It has been launched in June 2010 and is expected to grow in volume and scope over the total period of 2010 to 2020.

REFERENCES

[1] "A Technology Roadmap for the Communication on Investing in the Development of Low Carbon Technologies (SET-Plan)", Commission Staff Working Document, COM(2009) 519 final (2009), see http://eur-lex.europa.eu.

[2] W.C. Sinke et al., "A Strategic Research Agenda for Photovoltaic Solar Energy Technology", European Photovoltaic Technology Platform, Office for Official Publications of the European Union, Luxembourg (2007), ISBN 978-92-79-05523-2.

[3] W.C. Sinke et al., "Today's actions for tomorrow's PV technology - An implementation Plan for the Strategic Research Agenda of the European Photovoltaic Technology Platform", Office for Official Publications of the European Union, Luxembourg (2009), ISBN 978-92-79-12391-7.

[4] SET for 2020: Solar Photovoltaic Electricity - a Mainstream Power Source in Europe by 2020 (Executive Summary), European Photovoltaic Industry Association (2009), see www.setfor2020.eu.