22 May 2013

SET-Plan

SOLAR EUROPEAN INDUSTRIAL INITIATIVE (SEII)

PV IMPLEMENTATION PLAN 2013 – 2015

APPROVED BY THE SEII TEAM

Table of Contents

The Solar Europe Industry Initiative: building our solar future

The global photovoltaic (PV) solar energy sector is in a period of transition. The photovoltaic industry faces the consequences of a temporary, but nevertheless severe production overcapacity. The related rapid price erosion and industry shakeout have affected all involved and have led to uncertainty about the future of the sector. The market continues to grow by double digits, and reached more than 100 gigawatt cumulative installed capacity in 2012.

In Germany, an impressive 6% of all electricity is generated by PV. The strength of this technology is further illustrated by the fact that the cost of electricity from PV has recently fallen below that of offshore wind turbines. This and future development will broaden the range of options to reach the renewable energy targets for 2020 and beyond. Enabled by the strongly decreased prices, major self-sustained markets are developing in conjunction with incentive-driven markets, changing the nature of the businesses.

Recent projections based on the evolution of the competitive position of PV electricity indicate that the global market may reach the terawatt-level much sooner than anyone expected a few years ago. These projections even hold assuming that acceptable profit margins over the entire value chain are achieved (which is not the case today), allowing a healthy development of the sector. In other words: the current industrial crisis, dramatic as it may be, is not an indicator of an underlying technology crisis. On the contrary, it is only a ripple on a trend of robust and spectacular long-term industry growth. Europe can simply not afford to ignore the great opportunities in terms of energy and economy that come with this growth. The challenge is to face the fierce global competition by building on the strong starting position in terms of technology and markets and by focusing on aspects where Europe can make a clear difference.

The Solar Europe Industry Initiative (SEII) was established 3 years ago with exactly that aim. It describes the road to 2020 for the entire European PV sector, from materials to systems and beyond. The (rolling) SEII Implementation Plan describes the concrete fields of action. The first Implementation Plan covered the initial period of the SEII (2010-2012) during which period Member States, the European Commission and actors in the PV community began to work together in new ways.

The current Implementation Plan covers the period of 2013-2015 and addresses the challenges reflecting the changing PV landscape. Since the PV sector is still in the middle of this period of transition it is not yet possible to give final answers and this Implementation Plan describes “work in progress”. However, there is one important underlying ambition that is robust in spite of all uncertainties: Europe is resolved to continue to play an important role in the large-scale global manufacturing and deployment of PV that lies ahead of us. This relates to the role of PV in the electricity mix of Europe as well as to the European industry supplying innovative and competitive products and solutions to markets worldwide.

Innovations in all parts of the PV value chain are crucial for future success. By investing in research, development and demonstration in this period of crisis, Europe positions itself to benefit from the growth that will definitely continue once the crisis comes to an end. That is the essence of this Implementation Plan.

1. Introduction to the list of priorities

The **Solar Europe Industry Initiative (SEII)** has been launched in the framework of the Madrid SET Plan conference in June 2010. The SEII addresses both Photovoltaic and Concentrated Solar Power technologies. The scope of the initiative is to align agendas and resources of the EU, Member States, industry and academia in the field of industrial research and innovation with the aim of accelerating the development and deployment of solar technologies.

Every three years the SEII produces an Implementation Plan (IP) which indicates a detailed list of priorities on which common efforts should focus. The IP is coherent with the PV long-term technology roadmap and is in line with the Strategic Research Agendas (SRA) which is produced by the **European Photovoltaic Technology Platform (EU PV TP)**: a network involving research centers, academia, member states representatives and industry. Indeed, representatives of the EU PV TP constantly participate in the SEII works and contribute to the overall consistency of the efforts. Both documents, SRA and IP, provide an important input to the work programmes implementing the FP7 and Horizon 2020 in the future.

Another important stakeholder contributing to setting the EU energy R&D agenda in the field of energy is the **European Energy Research Alliance (EERA)**. The EERA is a network of leading European research institutes working together for the development of new energy technologies. At the core of the EERA are the Joint Programmes (JP). These are initiatives establishing permanent collaborations among national research institutes focusing on specific energy technologies such as PV. The coordinator of the JP Photovoltaic strand is member of the SEII team. SEII, with the industry in the driver's seat, and EERA JP PV, with the research sector taking initiative, represent complementary efforts. Together they support the SET-Plan priorities for PV and cover a broad range of R, D & D needed for success.

Since its launch in 2010, the overall objective of the SEII has been the reduction of the cost of PV generated electricity (€/kWh). The main pillars of the first roadmap have been the cost reduction of the technology, increased lifetime of PV systems, reliability of all components and sustainability of materials and manufacturing processes.
Great cost abatements in manufacturing have been made possible by the numerous innovations that have moved "LAB to FAB" and the achievement of multi-gigawatt production capacities. The deployment of all PV technologies has followed a rapid expansion as well, making PV one of the important players in the EU electricity generation mix. With 69 GW of cumulative installed capacity connected to the grid in the EU and a yearly production estimated close to 80 TWh, PV today provides 2.6% of the electricity demand at EU level and 5.2% of the peak demand[1].

As the path towards the goal of up to 12% of European electricity demand provided by PV by 2020 continues, greater attention will be dedicated to the integration of PV in the EU electricity grid. The rapidly evolving EU energy landscape demands frequent updating of the Implementation Plan of the SEII to keep up with technological and system integration challenges.

This Implementation Plan and the detailed R,D&D priorities presented in this section address the second 3-year period of the SEII and have been developed in the context of the current PV market, as discussed in the Introduction. In relation to the first SEII theme, this Plan concentrates on the performance and quality aspects of PV technology, whilst ensuring that these are accomplished at acceptable manufacturing costs. Quality, in all its forms, is seen as a major driver for a competitive European industry. Given the rapid growth of PV implementation in the last few years, the

[1] EPIA Market report 2012

second SEII theme is addressed by concentrating on the issues relating to large scale integration of PV into the electricity grid.

The R&D&D topics are divided into three pillars representing the major thematic areas required to make progress against the overall SEII PV roadmap to 2020. Within each pillar, the topics are then divided further by PV technology or topic area.

Pillar A: This pillar addresses the technology developments required for both performance enhancement and associated cost reduction at the PV system level. The development areas are divided into three chapters, A1 – A3, dealing with different PV technologies, namely wafer silicon technologies, thin film and emerging/novel technologies and concentrator PV (CPV) technologies. These three areas represent both current commercial cell /module technologies and those which are under development and with the potential to make a commercial contribution in the timeframe of the SEII. There are then two chapters, A4 and A5, dealing with topics at the systems and applications level, namely building integrated PV systems and Balance of Systems (BOS) requirements. The last chapter, A6, deals with cross cutting issues such as testing, modelling and technology demonstration. The topics in Pillar A directly address performance and lifetime enhancement, coupled with the reduction of manufacturing costs.

Pillar B: This pillar addresses the issue of quality and lifetime enhancement. It details cross-technology projects addressing quality assurance, reliability at module and system level and issues of sustainability including life-cycle assessment and recycling of components.

Pillar C: This pillar addresses the implementation of PV technology, especially in regard to grid connection. In comparison with the previous Plan, it has a greater emphasis on the issues relating to large scale integration, to reflect the rapid increase in the PV market in Europe recently and to facilitate the achievement of the SEII targets for electricity contribution. Topics include variability, flexibility of supply, aggregation, quantification of solar resources and active monitoring and control.

Detailed tables representing topics in each Pillar have been provided. In each table, the topics have been assigned one of two priority levels. All topics are important to the advancement of the sector as addressed by this implementation plan. Priority 1 topics are those that should be considered in initial funding rounds, with Priority 2 topics being added as soon as funds allow. The benefit of pursuing the development at European level and the risk level are also estimated, using the scale of I (low) to III (high). The level of risk is one of the criteria to be considered when determining the optimal ratio of public/private investments. Projects bearing a higher level of risk should be supported through a higher share of public funding.

Pillar A: performance enhancement & energy cost reduction

A.1 Wafer silicon technologies

Context	Wafer-based crystalline silicon technologies have a leading position among the commercially available PV technologies. Through **optimised production processes**, **product development** along with the tailored development of **equipments** and **materials,** this cluster of technologies has achieved remarkable advancement in cell efficiencies and production cost decrease. While the decline in manufacturing costs is steadily pushing PV technology toward competitiveness with conventional sources of electricity, increased product quality is emerging as one of the factors that can contribute to the success of the EU PV manufacturing at global level. Traditional innovation goals in manufacturing processes of wafer silicon technologies, therefore, will have to be accompanied by the introduction of greater automation, standardisation and in-process monitoring. A stronger focus on quality at product level will translate into increased efficiencies and yields resulting in greater energy production and long term reliability of the technology, coupled with reduced energy payback times.
Goals	• Sustainably reduced manufacturing costs per watt • Optimisation of production yield • Increased cell and module efficiencies • Increased competitiveness of the EU industry (equipments and products) at global level

Topic	Priority level	EU added value	Level of risk	Estimated total budget (M€)	Estimated public contribution
A.1.1 New low-energy silicon feedstock technologies for reduction of manufacturing costs.	1	II	II	60	40%
A.1.2 Silicon crystal growth techniques for high quality, high speed and re-use of crucibles. Quasi-mono products are included here.	1	III	II	40	60%
A.1.3 Advanced, automated, low/zero-loss wafering techniques for efficient material utilization by reducing silicon usage to 4 g/W by 2015. Wafer-equivalent technologies are included here.	1	III	II	45	40%
A.1.4 High-throughput automated processes for manufacturing, advanced, low cost, high-efficiency cells and modules, including process equipment (up to 0.4% multicrystalline and 0.5% monocrystalline, yearly increases on module level). Heterojunction a-Si/c-Si and hybrid IBC cells are included here.	1	III	II	120	60%
A.1.5 From LAB to FAB: pilot-line demonstration of at least 2 high-efficiency, low-	2	III	II	110	40%

cost approaches from the above priorities (A.1.1 - A.1.4).					
Total Budget				**375**	
Specific KPIs	2012	2015			
	16 -19 (~20.5%[2]) on module level	17.5 – 20.5% (22 %) on module level			

[2] All KPIs for efficiencies refer to commercially available modules, not to cells or modules efficiencies achieved in laboratories.

A.2 Thin-film & emerging/novel technologies

Context	Research and industry activities on processes and materials have yielded remarkable results in the thin film sector. Depending on the type considered, thin film technologies offer new application possibilities and some additional benefits. Examples are (related to) flexibility, low weight, good aesthetics, partial transparency, short Energy Pay Back Time (EPBT), good high temperature and/or low light performance, low material consumption and integrated manufacturing. However, to fully benefit from this, thin film technologies need to achieve higher module efficiencies. While higher efficiencies for photoactive layers remain still a key issue, it is also the development of the module that can play a major role (encapsulation, glass plus antireflective layers, transparent conductive oxides – TCOs –etc.). Another critical issue for thin film technology is the ageing behaviour and consequent estimate of lifetime. Equal attention should be paid to cost decrease. Current manufacturing processes require the use of costly production equipment and, in low production capacities that is a threat. It is therefore in this area that potential for cost reduction lies. Better material utilisation is also needed, as well as the research on low cost synthesis approaches for the materials development. Emerging technologies such as organic PV have demonstrated improvements in efficiencies as well as in stability issues. There are now pilot production lines that should be further supported. Those technologies can play an important role due to their specific properties and tuning possibilities, for instance in the building sector (BIPV). Novel technologies include quantum and nanoparticle technologies, as well as high quality direct bandgap materials with optical confinement, currently at an R&D level. More emphasis should be given to these technologies that could bring highly competitive products and propel the PV industry into another evolutionary era by possibly overcoming the Shockley-Queisser limit for single-junction solar cells.
Goals	• Advanced application possibilities • Sustainably reduced manufacturing costs per watt • Optimisation of production output (power/energy) • Increased cell and module efficiencies • Increased competitiveness of the EU industry at global level

Topic	Priority level	EU added value	Level of risk	Estimated total budget (M€)	Estimated public contribution
Thin Film					
A.2.1 Low cost, large area deposition process equipment, global deployment of laser technology and control methods (e.g. roll to roll, high rate, new precursors, low cost equipment)	1	III	II	100	40%
A.2.2 High efficiency thin film cell designs and module manufacturing processes (novel light management concepts and new structures) in order to achieve results of 12-16% on module level considering all inorganic TF	1	III	II	80	40%

technologies (a-Si, CdTe and CIGS) **A.2.3** From LAB to FAB: pilot-line demonstration of at least two 2 novel low-cost, high-efficiency approaches	2	III	II	55	40%
Emerging/Novel					
A.2.4 High efficiency emerging and novel technologies cell designs and module manufacturing processes (novel light management concepts and new structures)	1	III	III	25	80%
A.2.5 From LAB to FAB of at least 2 emerging and/or novel low cost printable PV technology approaches	2	III	III	20	80%
Total Budget				**280**	

Specific KPIs		2012	2015
	Thin Film	8-14% on module level	12-16% on module level
	Emerging technologies	4-5% on module level	6-8% on module level

A.3 Concentrator PV (CPV) technologies

Context	Concentrator PV technology has shown progress beyond expectations in cell and module efficiencies. Both high CPV technologies (HCPV), normally from 300 to 1000 concentration factor and based on III-V semiconductor compounds, and low CPV (LCPV), normally below 100 concentration factor and based on Si, have developed following a different track and each achieving their market share. The performance of the cell remains the central element of the success of the technology and R&D efforts to increase efficiencies remain valid in the coming years. The deployment of the technology has not followed at the same speed. This is mostly due to the limited availability of long term reliability data resulting in a purely perceived technological risk. CPV has a strong potential to increase the efficiency much faster than other PV technologies revealing further cost reduction. Advancements in this area will be achieved by putting more focus on system development. To ensure that the full potential of cost reduction at system level is achieved, it is necessary to follow a holistic approach looking at the optimisation of the whole system. This will grant both cost reductions and increased yearly energy yields. As CPV becomes more widely deployed, cost reductions will also be achieved through competition and standardisation.CPV technologies can create a high value for EU all along the value chain and develop an innovative and globally competitive EU industry.
Goals	• Increase cell and module efficiencies • Sustainably reduced manufacturing costs per watt • Optimisation of production yield • Large scale introduction of manufacturing with advanced and flexible production lines • Development of a systemic approach to improve the whole CPV system efficiency, yield and cost

Topic	Priority level	EU added value	Level of risk	Estimated total budget (M€)	Estimated public contribution
A.3.1 Industrial low-cost, automated and optimised manufacturing processes for high-efficiency concentrator cells for LCPV and/or HCPV, including process equipment and control methods.	2	III	II	45	40%
A.3.2 Industrial low-cost automated manufacturing processes for improved concentrator optics, for achieving optimum concentration factor for specific technology. Process equipment is included.	2	III	II	35	40%
A.3.3 High-throughput, high-precision low-cost assembly technology for CPV modules	1	III	II	35	40%
A.3.4 Increase the cell efficiency towards 50% by using new cell architectures and industrial equipment to produce these cell structure	1	III	II	55	60%
A.3.5 Proof of concept demonstration projects for optimization techniques of complete CPV systems (module, BOS).	1	II	III	55	40%

Total Budget			**225**
Specific KPIs		2012	2015
	HCPV	29-32% on module level	32-35% on module level
	LCPV	18-21% on module level	> 22% on module level

A.4 Building-integrated photovoltaics (BIPV)

Context	The multifunctional role of the BIPV application makes this an important sector to develop, especially taking into consideration future targets on zero energy buildings and smart cities, but provides a challenge in the predominance of relatively small capacity systems. Facades of commercial and public buildings represent a vast and largely unexploited, market segment available to almost all PV technologies. Even though there are minimum technical requirements for a successful integration of BIPV in buildings, this application has to fully convince architects and designers of its versatility and additional functionalities and to meet the criteria for economic viability. Furthermore, for BIPV modules and systems, inherent security mechanisms have to be developed which assure their electrical and other safety. In order to substitute construction materials, in particular, BIPV has to show its capability of generating electricity, without compromising the basic functions of the building envelope (e.g. thermal insulation and illumination) while respecting national building codes. In this sense, the realization of several demonstration projects, focusing on the flexibility of the application (e.g. large/small, different geometries etc), the aesthetics (in new buildings but also in older constructions of historical/heritage value) and the compliance with the building sector standards of innovative BIPV products, will play a particularly important role. Large scale demonstration projects within the concept of "Solar Cities" can be one stepping stone for proving the feasibility of large-scale deployment potentials in urban areas.
Goals	• Development of low- cost multifunctional BIPV products that can be used as certified construction materials • Flexible production lines for manufacturing a wide variety of products, in different scales and on different substrates • Flexibility of design and improved aesthetics

Topic	Priority level	EU added value	Level of risk	Estimated total budget (M€)	Estimated public contribution
A.4.1 Development of new multifunctional PV-based products including new installation concepts.	1	II	II	25	50%
A.4.2 Industrial automated low-cost manufacturing process and control methods, including development of new flexible equipment for different production lots with different geometries (e.g. small or large production lots, flexible compounds, different substrates)	1	III	II	35	40%
A.4.3 Optimisation of cell performance, long term higher energy output and improved optical appearance at reduced costs (Euro/m²) together with inherent security mechanisms	2	III	III	40	60%
A.4.4 Proof of concept large scale demonstration for BIPV, providing the necessary/traditional building functions, complementary to the European Energy Performance of Building Directive (EPBD) including energy generation and aesthetics and according to relevant building codes.	1	III	II	50	50%

Total Budget				**150**	

A.5 Balance of system

Context	Much of the R&D efforts in recent years have focused on the development of high efficiency cells and modules at low cost, resulting in significant advances in both areas. However, balance of system (BoS) components (including the inverter) are also an important part of the value of the PV system and, accordingly, the reduction of their cost along with performance enhancement is considered very important for the overall PV industry. Lower cost manufacturing processes that will result in an increasingly reliable component with longer-term performance is a key goal. New components e.g. power optimizers, micro-inverters, new battery technologies developed for PV applications, further safety components should be assessed against the reliability and cost reduction criteria. Inverters have already achieved the desired efficiencies; however the current focus is mainly shifted to the functionalities, the diagnostic, control and communication features that should be included in order to comply with the grid integration requirements (see Pillar C) and also to extending the life time in different operating conditions. Even though each component has specific needs and deserves a dedicated R&D path, it is only through a systemic approach based on the interaction of each component, that a real optimization of the whole system can be achieved. Different applications with different PV technologies will require different BoS solutions.
Goals	• Increased energy yields/reduced system losses • Fault prediction and long term reliability of systems • Lower BoS costs meaning lower system costs

Topic	Priority level	EU added value	Level of risk	Estimated total budget (M€)	Estimated public contribution
A.5.1 Low-cost durable mounting structures, cabling and electrical components (e.g. PV connectors, DC switchgears, further safety components etc.) for small or large PV systems. Holistic design of module and mounting structure to minimize cost. Components for reducing system losses e.g. modules and inverters for operation at a system level >1000 V and modules for operation under partial shading are included here.	1	II	II	60	40%
A.5.2 Improved lifetime and low-cost power electronics (i.e. inverter lifetime >20 years of operation). PV optimizers, (micro)-inverters, monitoring systems, security devices etc are included here. Inverters for PV hybrid systems may also be included here.	2	I	II	60	40%
A.5.3 Low-cost, high-accuracy tracking systems/platforms (single and double axis) for different applications.	2	II	III	40	50%
Total Budget				**160**	
		2012		2015	

Specific KPIs	CAPEX for large systems (>2.5 MWp) (€/Wp)	1.1-1.6	0.9-1.1[3]
	Inverters lifetime (years)	>20	>25

[3] Temporary phenomenon linked to market dynamics, such as oversupply, can lead to lower figures based on misleading indicators and unsustainable selling prices available on the market. Such a scenario, however, is not the goal of the SEII. The KPI refers to a sustainable reduction of production costs and healthy profit margins for modules or other PV systems components manufacturers.

A.6 Cross-cutting & system perspective

Beside their specific needs, all PV technologies can benefit from the development of a certain number of shared R&D needs. Those "cross-cutting" issues can be singled out and organised in a dedicated set of priorities. Such an approach will allow their optimal development. BoS (A5) and the topics in Pillar B can be considered as cross-cutting. However, the gravity and the importance of those clusters, requires separate approach. Even though different technologies and applications require dedicated system design and installations, some basic features (standardization, system reliability, PV modeling etc) and considerations can be shared by all of them. The aim of these horizontal topics is to identify key points for simultaneously optimizing the PV system layouts, increasing energy yields and decreasing costs.

- Increased overall system performance/reduced losses
- Reduced system costs
- Enhanced PV system bankability

Topic	Priority level	EU added value	Level of risk	Estimated total budget (M€)	Estimated public contribution
A.6.1 Standardize manufacturing equipment and processes eligible for all PV technologies and standardization of key module components/materials (e.g. glass, encapsulants etc.)	2	III	I	15	40%
A.6.2 PV research infrastructures, testing facilities (outdoor and/or indoor) and procedures in order to accelerate innovations and evaluate costs.	1	II	I	20	60%
A.6.3 Develop tools and techniques dedicated for PV modeling, characterization and control purposes for the whole value chain and along all the process steps.	2	II	II	15	40%
A.6.4 Demonstration project for realization of large scale new PV technology power plants and/or new concepts for PV system technologies (e.g. 1500 VDC) in order to enhance confidence from the financial sector.	1	II	II	35	30%
Total Budget				**85**	

Pillar B: Quality assurance, long term reliability and sustainability

B. Quality assurance, long term reliability and sustainability

Context

This Pillar is dedicated to cross cutting issues that will continue increasing in importance as PV technologies claim an increasing share of wholesale and retail electricity generation.

Performance improvements of PV technology aimed at increasing efficiencies are crucial to the reduction of overall electricity costs.. Additional aspects such as quality, long term reliability and sustainability, however, play a determinant role for allowing a reliable comparison between products. These three key aspects are highly interrelated and the improvement of these aspects as a whole will transform the EU PV industry for the better, making the PV system in the short and mid-term more technically competitive and a guaranteed investment for even the most skeptical by minimizing the potential risks and reducing the PV electricity generation costs.

Quality assurance comprises all the different activities and available standards that can be applied and increases the overall performance of the PV system by making sure that the outdoor performance (power and energy output) and safety requirements are aligned with relevant standards and specifications. Quality assurance includes systematic monitoring, inspection and measurements embedded in each production process and associated equipment from raw materials to the end installation (field-tests), including transportation and final recycling. Quality assurance activities should be kept updated based on the technology trends.

Long term reliability of PV systems refers to maintaining the high quality and performance of the PV system until the pre-defined end of life without retrofitting.

The sustainability aspect of this Pillar includes life cycle analysis (LCA) and evaluation of the environmental impact of the PV technology (e.g. CO_2 footprint, Energy Pay Back Time (EPBT) etc.). Applied to materials, sustainability is translated to availability of certain material, new materials and recycling processes.

Goals

- Increase competitiveness (economical and technical)
- Minimize the environmental impact and use of materials
- Develop recycling processes
- Develop harmonised EU quality standards and/or guidelines

Topic	Priority level	EU added value	Level of risk	Estimated total budget (M€)	Estimated public contribution
Quality assurance					

B.1 Improvement and/or apply in-line EU-harmonized low-energy processes and production control techniques and procedures and in general introduce the concept of Total Quality Management (e.g. statistical process control, failure testing). The necessary software development for performing the quality control is included here, together with analytical tools for rapid onsite quality control of cells and modules.	2	III	II	75	50%
B.2 Improvement of guidelines for optimum transportation, installation, configuration, fulfillment of safety requirements and monitoring/evaluation for enhancing the energy yield and overall performance at the system level.	2	III	II	40	50%
Long term reliability					
B.3 Develop and apply system design techniques for achieving high outdoor long-term system performance >25 years at 90% of the initial Performance Ratio (PR) at low cost and potential reduction of the use of materials in line with priority B.1. This includes joint efforts to gain understanding of ageing mechanisms and the development of dedicated accelerated test procedures. Issues like thermal management, natural cooling, optimum orientation etc. are also included here.	1	II	III	65	40%
B.4 New low-cost, long-lifetime material alternatives (e.g. encapsulation materials, glass, antireflective layers etc) and module designs that will lead to longer-term reliable PV systems and reduce degradation effects (e.g. potential-induced degradation (PID)). This should be in line with B.5 priority. This includes joint efforts to gain understanding of ageing mechanisms and the development of dedicated accelerated test procedures. PV product designs that will facilitate the dismantling and recovery of materials and components (recycling) are also included here.	1	III	III	75	60%
Sustainability					
B.5 Improved life-cycle assessment (e.g. carbon footprint and EPBT etc) of all PV technologies and BOS under detailed guidelines and feedback of the results to the industry.	2	III	III	35	60%
B.6 Development of design criteria facilitating low-cost efficient recycling processes according to relevant EU standards and directives for new designs for all PV technologies and BoS components. Development of easy-to-access recycling infrastructure available to all is included here.	1	I	II	85	50%
Total Budget				**375**	

Pillar C: electricity system integration

C.1 Enabling large scale deployment

Context	Political and market initiatives that have been put in place in several European countries, along with the technological improvements and fast price decline in PV systems, have spurred strong growth in PV markets over the past few years, showing resilience in the face of harsh economic conditions. Thanks to its decentralised nature and its ability to lower prices due to its modularity, PV may continue to outperform all growth forecasts in the years to come. Obviously there remains a lot of room for improvement towards overall performance enhancement and electricity generation cost reduction as has been demonstrated above in Pillars A and B to boost PV competitiveness even more. However the increasing share of the electricity mix that PV has enjoyed in the last few years has also shifted the attention to grid integration challenges. The topics in Pillar C have gained significantly in importance since PV is not a "sole player" anymore, but is becoming a mainstream technology that can participate in system operation, both affecting and being affected by all the other stakeholders of the electricity market (technically and economically). Taking into consideration the EU targets for decarbonisation of the electricity sector and the RES/PV deployment scenarios for 2020 and beyond, PV will need to integrate seamlessly into the electricity grid. This will require changes from grid operators, from policymakers and from the PV industry itself, although the challenges are not insurmountable. With a more diversified, variable and electricity-intensive energy mix, the future European electricity system will have to be more interconnected, more flexible and more decentralised. Flexibility introduces requirements such as fast start-up and shutdown of generators, following ramps, start-up reliability and load predictability, frequency control and ancillary services. Addressing the challenges will build trust in the PV technology and will directly enhance the market penetration, which will have a consequent positive effect on the PV industry as a whole.
Goals	• Enable high penetrations of PV whilst minimizing the cost impact • Identify, analyse and valorise fully the potential of PV technology • Integrate storage solutions in PV systems • Create a continuum among all the stakeholders (e.g. Transmission System Operators /Distribution System Operators/ PV developers/utilities etc) • Increase the overall flexibility of the power system • Overcome bottlenecks in the distribution grid • Ensure a fair financing of all parties involved

Topic	Priority level	EU added value	Level of risk	Estimated total budget (M€)	Estimated public contribution
C.1.1 Implementation of technical solutions for improved PV integration. Demonstration of power and energy management strategies, ancillary services and	1	III	II	200	50%

other functionalities required by an inverter based system according to national or European grid technical specifications. The development of such specifications is included here.					
C.1.2 Proof-of-concept for technical feasibility of very high levels of PV penetration either in urban or isolated environment, align with priority *C.1.1.* The concept of "Solar Cities" and "Solar Islands" is included. Field tests, monitoring and evaluation of the compliance of the hardware are also included.	1	III	II	200	50%
C.1.3 Increase the overall system flexibility by improved PV forecasting techniques and electricity prediction models applied in large balancing areas and in combination with storage solutions (centralized or decentralized) and/or energy efficiency solutions and/or demand side management solutions. Complementarities with other renewable sources (preferably wind), other flexible generation assets and aggregated demand response are included. PV should be the central asset.	1	III	III	120	60%
C.1.4 Identify quantitatively the grid costs generated by high shares of PV into the system and elaborate solutions based on a cost-benefit analysis to minimize the costs. Solutions should follow priority C.1.1 and/or C.1.3. Study case analysis. Evaluation of different market models is included.	2	III	II	85	50%
C.1.5 Proof of concept for smart grid projects in combination with smart PV system (meters and other relevant hardware or software) that will assess the operation of a wider range of assets/solutions (e.g. storage, heat pump, electric vehicles, demand side management etc) under a common communication standardized protocol and following different management techniques that can increase hosting capacity. The impact on the distribution network should be evaluated as well as the costs. PV should be the central asset. Virtual Power Plant (VPP) concept is included here.	1	III	III	125	40%
C.1.6 Proof of concept for the potential of aggregation. Aggregation can refer to aggregating and controlling small PV systems (e.g. roof top) or aggregating several "smart systems" or VPPs as those defined in *C.1.5.* The focus should mainly be on trans-European aggregation and the portfolios aggregated should contain a large share of power from photovoltaics.	2	III	II	85	40%
Total Budget				**815**	

C.2 Solar resources and monitoring

Context	The increased role of PV in the European energy mix demands for a greater attention to all the aspects related to planning and predictability. Platforms financed in this cluster should aim at gathering and disseminating accurate and reliable information facilitating all the aspects of PV integration. The data should be useful for various stakeholders groups in all EU Member States.
Goal	• Gather and disseminate information facilitating the integration of PV in the EU energy mix

Topic	Priority level	EU added value	Level of risk	Estimated total budget (M€)	Estimated public contribution
C.2.1 European "PV Monitoring Centre", aimed at gathering and disseminating a variety of monitoring data (including information on failure modes) and information for benchmarking, including technology, industry, market and policy aspects (mainly carried out by SETIS).	1	III	II	20	60%
C.2.2 Development of simulation and monitoring tools (early fault detection, weather forecasting, modeling and simulation of ancillary services, etc.). These tools should rely on open communication protocols and ensure compatibility of PV generation with distribution management systems, state estimators for distribution and transmission, protocols related to power market operations and balancing and data collection from regulatory or public agencies and asset management systems.	2	III	II	20	60%
Total Budget				**40**	

2. Budget overview

As explained in chapter 4 each financial instrument funding research, development and demonstration projects, should be chosen in accordance with the type of action considered. As a general principle, actions with a high EU added value warrant a high EC/MS (MS = Member States) funding ratio, while public/private funding ratios are highest for high-risk and/or long time-to-market actions.

Enabling research/policy actions	Pre-competitive research	Manufacturing technologies: demonstration & test facilities	Market uptake/innovation/private infrastructure
Total public funding level: 70%-90%	**Total public funding Level: 50 % - 70%**	**Total public funding Level: 30%-50%**	**Total public funding Level: <30%**
EU grants, MS for relevant actions	**EU grants, MS for relevant actions**	**EU grants, MS, Equity and loans (EIB), NER-300**	**MS, Equity and loans (EIB), NER-300**
A.2 Emerging/Novel technologies	A.1.4 High-throughput manufacturing processes for low cost, high-efficiency cells and modules	A.1 Wafer silicon technologies *(except A.1.4)*	B.6 Development of recycling processes and easy-to-access recycling infrastructures
C.1.2 Proof of concept of very high levels of PV penetration	A.3.1 Industrial manufacturing processes for high-efficiency concentrator cells	A.2 Thin Film Technologies	A.6.4 Realisation of large scale PV power plants
C.2 Solar resources and monitoring	A.3.2 Industrial manufacturing processes for improved concentrator optics	A.3 Concentrator PV (CPV) Technologies	C.1.4 Identify quantitatively the grid costs generated by high shares of PV into the system and elaboration of solutions
	A.4.1 Development of new multifunctional PV-based products	A.4 Building-integrated photovoltaics (BIPV)- *(except A.4.1 & A.4.3)*	
	A.4.3 Optimisation of cell performance	A.5.1 Low-cost mounting structures, cabling and electrical components	
	A.5 Balance of system (except A.5.1)	A.6 Cross-cutting & system perspective (except A.6.4)	
	A.6.1 Equipment and processes standardization	C. 1 Enabling large scale deployment *(except C.1.3 & C.1.4)*	
	B. Quality assurance, long term reliability and sustainability		
	C.1.3 Increased overall system flexibility		

Table 2: Distribution of the project clusters based on the state of technology development.

The budget needed to cover the core focus of the SEII during the period 2013-2015 (selected priority areas) is presented in table 3 and figure 3 and 4 (next pages).

R&D and demonstration cluster	Estimated total Budget for 2013-2015 (M€)	Estimated public share[4] (%)
Pillar A: performance enhancement & energy cost reduction		
A.1 Wafer silicon technologies	**€ 375**	**40-50%**
A.2 Thin-film & emerging/novel technologies	**€ 280**	**50-60%**
A.3 Concentrator PV (CPV) technologies	**€ 225**	**40-50%**
A.4 Building integrated photovoltaics (BIPV)	**€ 150**	**40-50%**
A.5 Balance of system	**€ 160**	**40-50%**
A.6 Cross-cutting & system perspective	**€ 85**	**40-50%**
Pillar B : Quality assurance, long term reliability and sustainability		
Quality assurance	**€ 115**	**50-60%**
Long term reliability	**€ 140**	**50-60%**
Sustainability	**€ 120**	**50-60%**
Pillar C: system integration		
C.1 Enabling large scale deployment	**€ 815**	**40-50%**
C.2 Solar Resources and monitoring	**€ 40**	**60-70%**

Table 3: Budget breakdown for R&D & Demonstration

[4] Public contribution: refers to EU grants and to debt loans (100% from industry) or aided loans (in the form of for instance soft loans or loan guarantees). The definition will be given on a project by project basis (taking into account the bankability and risk associated to the project).

Looking at the overall period (2010-2020), about 9b€ need to be invested in order to reach the SEII objectives (as communicated in the EC Technology Roadmap (SEC(2009) 1295, 7 October 2009). This figure is the amount of expected contribution from the EU, industry and Member States through their national research programmes. The distribution of the investment should follow the following trend:

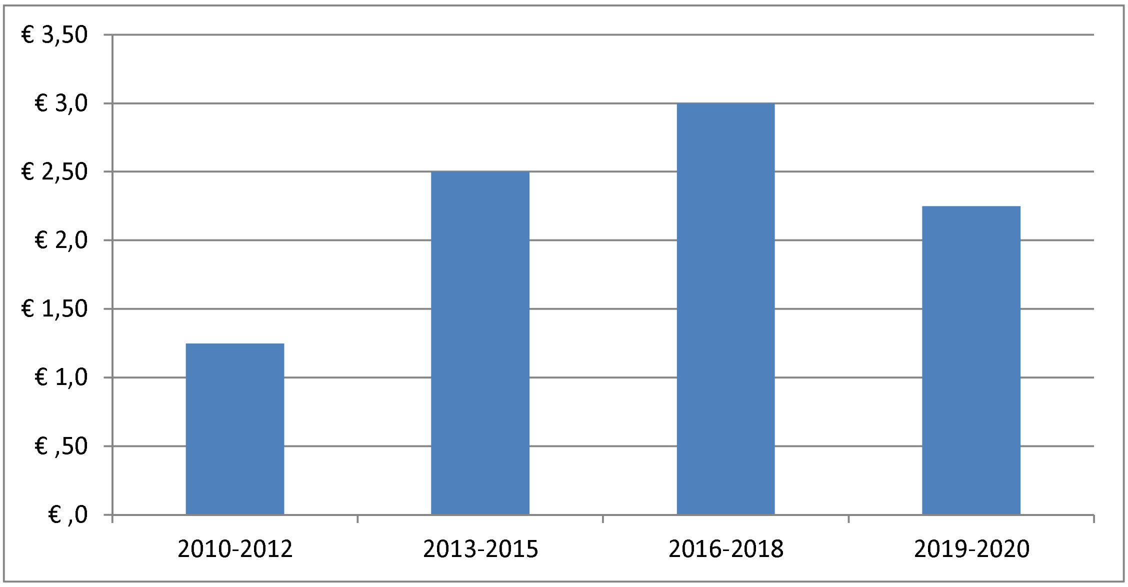

Figure 3.
Distribution of budgets by categories until 2020 (figures in bln €). The budget includes several financial tools available at European level ranging from Horizon 2020 to structural funds. It also considers the budget of the research programmes at national level as well as the industry investments in R&D.

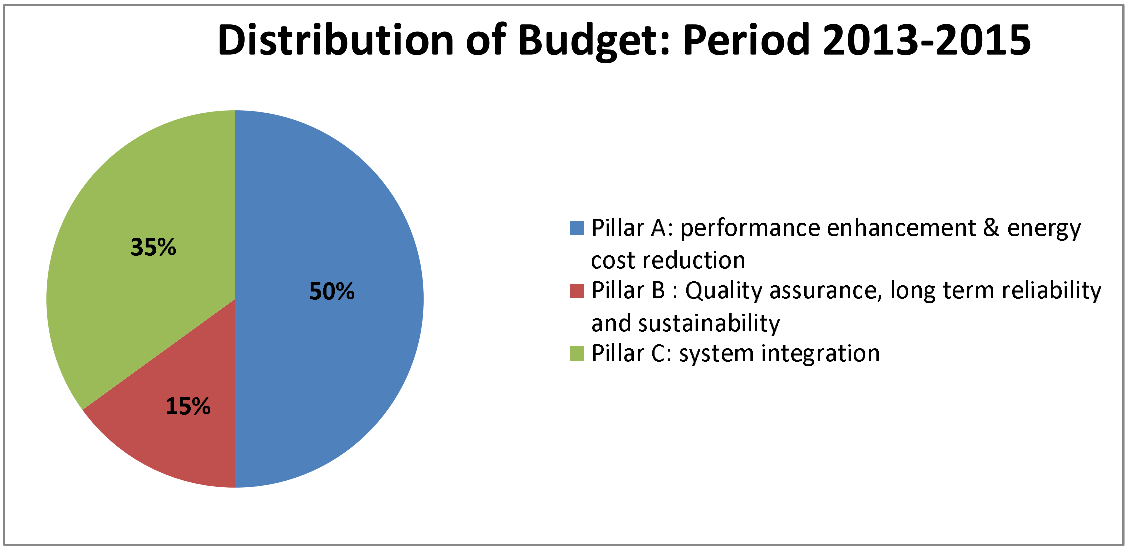

Figure 4. Distribution of budgets by categories until 2015

3. Governance

The implementation of the Solar Europe Industry Initiative is overseen by the SEII Team, whose remit includes both the photovoltaics and concentrated solar power activities of the SEII. The Team agreed the following structure and operating principles in May 2011 and these are expected to apply throughout the period of this Implementation Plan. The SEII Team reports to the SET-Plan Steering Group regarding the implementation of the Initiative.

Membership

- Member State (or Associated Country) representatives: 1 per Member State per sector (PV, CSP)
- 8 industry representatives, nominated by the respective industry association and/or Technology Platform: 4 representing PV and 4 representing CSP
- 4 representatives of the European Commission, with responsibilities relevant to the PV and CSP technology sectors
- 2 representatives of the European Energy Research Alliance (EERA)

Alternates are also identified for each of the membership categories.

Meetings of the SEII Team

Meetings of the SEII Team are convened by the European Commission on behalf of the Member States participating in the SEII. A minimum of two meetings per year is defined in the agreed procedures, but in practice the Team meets as often as is required to conduct the business of the SEII. To date, ten SEII Team meetings have been held. The meetings are chaired by one of the European Commission representatives.

Participants additional to the nominated Team members may be invited to participate in the meeting. These invitees may include members of other EIIs, members of complementary Technology Platforms or other relevant experts.

During the first period of the SEII, the SEII Team has considered the priorities of the Initiative, the development of funding mechanisms, such as the Solar ERA-NET recently implemented, and project priorities during the Team meetings. The opportunity for debate is limited by the time available within the meeting. It would be useful to explore methods for facilitating discussions between the PV industry and the Member State representatives outside, and preferably prior to, the Team meeting so as to be able make more rapid progress in the SEII and ensure that the Team meetings are as efficient as possible in elaborating the recommendations of the Team

SEII Team Responsibilities and Activities

The SEII Team has the following designated responsibilities:

- To approve, refine and update the SEII Implementation Plan (IP)
- To lead the implementation of the SEII, including definition of the most appropriate modalities taking into account the interests of the Member States and the need for overall coherence between the EIIs
- To monitor the progress of the IP through the defined KPIs
- To inform the Steering Group regarding the progress of the IP
- To address cross cutting issues, as necessary, in collaboration with other SET-Plan initiatives
- To ensure communication and interaction, where appropriate, with stakeholders and interest groups.

This Implementation Plan for the photovoltaics theme has been developed with technical input from the European Photovoltaics Industry Association, the European Photovoltaic Technology Platform and other stakeholders from the photovoltaic community. It is approved by the SEII Team and endorsed by the Steering Committee of the SET-Plan.

4. Main goals and KPIs 2013 - 2015

In order to monitor and evaluate the overall progress of the SEII, a set of Key Performance Indicators (KPIs) and reference systems have been defined. These indicators designate the long term goals for each set of priorities until 2020, as well as the intermediary milestones to be achieved within each area of activity considered in the IP (research, development, innovation and demonstration). All projects falling in the scope of the SEII, therefore, have to clearly demonstrate their direct link between their goal and the SEII KPIs. A constant flow of information from the projects toward the SEII team and the SETIS is required to enable an effective monitoring of the EII progression. KPIs are updated on regular basis to reflect the state of the art of the industry. The SEII KPIs are presented in table 4.

1. Goals of each pillar

For each pillar it is possible to single out the advancements that KPIs intend to measure.

a. **Pillar A: performance enhancement & energy cost reduction**

KPIs in this area refer to:

- PV electricity generation cost reduction (€/kWh)
- PV module efficiency increase (%)
- Turn-key system price reduction (€/kWp)
- # of advanced pilot lines for advanced technologies
- Inverter lifetime increase (years)
- Multifunctional products
- Demonstration of high-quality, versatile integration of PV in buildings and infrastructural objects (e.g. thermal & Noise Insulation, solar shading, substitution of the building skin)
- Price of system (€/kWp) for BIPV applications.

b. **Pillar B: Quality assurance, long term reliability and sustainability**

KPIs in this area refer to:

- Increase PV competitiveness (economical and technical)
- Improved use of materials, development of alternatives and minimization of their environmental impact
- Develop recycling processes

c. **Pillar C: electricity system integration**

KPIs in this area refer to:

- Increased overall flexibility of the power system
- Self consumption/Grid export
- Congestion management (e.g. curtailment)
- Peak demand ratio
- Voltage quality performance, Reactive power control, e.g. for voltage control
- Power quality by reducing flickers and harmonics
- Network losses decrease
- Investment cost, LCoE

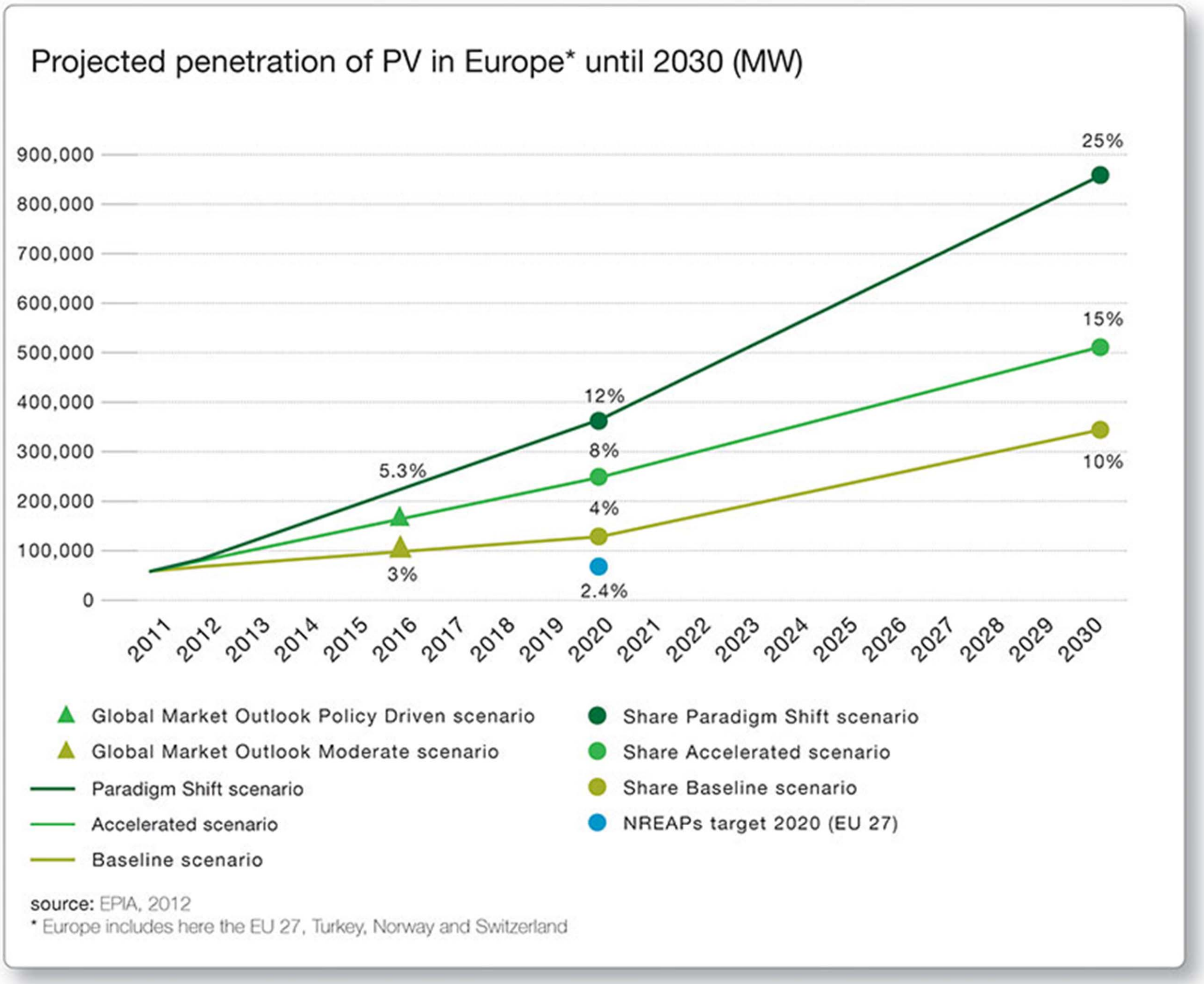

Figure 6: growing shares of PV generation connected to the grid require increased flexibility from the electricity grid

Table 4: PV technology state-of-the-art and major objectives/milestones for the next 10 years (numbers and ranges are indicative because of the spread in technologies, system types and circumstances, etc.)

Metric		BASELINE	TARGETS	
		2012	2015	2020
CAPEX for large systems – 2.5 MWp (€/Wp)[5]		1.1-1.6	0.9 – 1.1	0.8-1
Module efficiency (%)[6]	c-Si (high efficiency[7])	16-19 (20.5[8])	17.5-20.5 (22)	>21
	TF	8-14	12-16	14-20
	HCPV	29-32	32-35	38-40
	LCPV	18-21	>22	>24
Inverter lifetime (years)		>15	>25	> 30
Module 80% guaranteed power output time (years)[9]		25	30	>35
System performance ratio (%) [10] (for residential systems)		≈75	≈80	≈85
PV Production forecasting error / Root Mean Square Error (RMSE) (%) (for single plants and day-ahead predictions)[11]		8-11	Further reduction	Further reduction
Efficiency for novel technologies (% on module level)		NA	NA	>25
Efficiency for emerging technologies (% on module level)		4-5	6-8	>10
Performance stability of organic solar cells (years)[12]		<5	5 -10	>10

[5] The system price depends not only on technology advances, but also on the maturity of the market (which includes industry infrastructure as well as administrative costs).

[6] The efficiency as expressed here represents the total area efficiency of the module. The module efficiency affects the BoS (balance of system) cost. However, many more parameters define the BoS costs as these parameters impact the efficiency at PV array level. All KPIs for efficiencies refer to commercially available modules, not to cells or modules efficiencies achieved in laboratories.

[7] The efficiency as indicated between brackets refers to high efficiency c-Si PV modules, which are also sold at higher prices compared to the other c-Si PV modules.

[8] High efficiency commercial modules

[9] Because the lifetime of a PV project is rather difficult to estimate, we prefer to approach this by using the guaranteed power output. At the moment, most module manufacturers offer such guaranteed power output for a number of years. The current standard is 90% of the rated capacity after 10 years and 80% after 25 years. These values are however more conservative than the proven lifetime of certain PV projects which can be 30 years or even higher. Moreover, 25 years represents a conservative industry-wide average, including all PV technologies.

[10] The performance ratio (PR) that is described by international standards (IEC 61724) is the difference between the modules' (DC) rated performance and the actual (AC) electricity generation and is directly linked to the kind of installation. Key factors are also average module temperature, early faults detection and system design that also defines short and/or longer-distance shading effects. Normally for utility scale the PR is assumed around 5% higher.

[11] Considering larger PV portfolios and aggregated PV power at a regional level this error can go down to 4.5-5.5%. Such improvements are very important for the system operators for capacity management and scheduling.

[12] This encompasses the intrinsic stability of the materials used in the active layer, the stability of the cells' nanomorphology and the stability of the contact between metal conductors and organic semiconductors. The figures here reflect the roadmap for applications of organic solar cells starting from small electronic applications as it is the status today to BIPV applications until 2015 and grid connected applications until 2020.

5. Link with other EIIs

The successful implementation of several SET Plan industrial initiatives requires an increasing degree of interaction among the industries drafting the Implementation Plans. Also in the case of the SEII the coordination with relevant EIls will avoid overlaps in research activities and speed up the realisation of the SEII IP goals.

EEGI - *European Electricity Grid Initiative*

The increased importance of the "Pillar C: electricity system integration" within the new Implementation Plan has highlighted the need of interaction with the EEGI in particular. To this end in 2012, EPIA provided ENTSO-E, EDSO-SG with a list of R&D priorities to be included in the new EEGI Roadmap and Implementation Plan. Such exchange will ensure the complementarity of the two R&D roadmaps.

<table>
<tr>
<td>Short-term</td>
<td>

Observability of PV units as small as 100 kWp
Participation of PV units in voltage control, coordinated with the other voltage control facilities in distribution networks and protection plans
Voltage stability is still a critical topic. Reactive power as a function of power will be used in Italy soon, but the concept is still not sufficiently evaluated
Avoidance of unintentional islanding and protection of customers (closely related to the technical criteria for connection and requirements to inverters)
Anti-islanding protection and intended islanding: Islanding was already a topic in 2010 to 2012, but its framework has changed. The conflicting goals of island detection and system services (active power reduction in case of over production 50.2 Mhz) should be considered, together with communication and protection solutions to prevent islanding or to manage it in the future. The different national approaches should be taken into account when prefenting or managing islanding.
Safety, for low voltage PV back feeding the MV network
Personal safety is very well covered by existing requirements and implemented in existing products
Integration strategies of PV together with other primary energies (e.g. wind) to more controllable power plants / power delivery
Cost reduction of power electronics components (e.g. power plant controller)
Following a costs/benefits analysis approach when developing new services and communication itnerfaces.
Communication strategies that are low enough cost to be included in small production units, bearing in mind that ENSTO-E might require an ON-OFF signal down to 400W installations.
Handling of harmonic currents: more analysis of the grid evolutions are needed before defining new standards

</td>
</tr>
</table>

	• Improvement of forecasts for PV power (1 hour, 3 hours, 12 hours 1 day, 3 days) for scheduling of conventional power plants taking into account different technologies (flat panels, concentrated PV) and different possibilities (satellite, sky cameras, etc…) • Harmonic superposition for power plant interconnection and compliance estimation
Mid-term	• Observability of PV units down to 1 kWp • Communication safety (e.g. against malicious attack) • Frequency support services provided by PV systems • Technical aggregation of PV and other DER by the distribution utility, leading to their integrated management by the TSO/DSO for system operations. Analysis of the interactions between markets and system operation at all levels (transmission, distribution and PV owners). The impact on the business models of all stakeholders should be considered too. • Ensure the quality of the resulting power wave with high penetration of PV units • Unification of connection requirements to Pv deployment and reduce costs by standardization
Long-term	• Virtual power plants • Intentional island operation capability • Integration of large scale storage capabilities in the grid

Storage technology roadmap

The development in scale and scope of energy storage is one of the conditions that will enable further integration of renewable electricity sources in the electricity grid. There is no single energy storage option that can cover all requirements in all EU regions. Applications, technological development and market evolution will determine which type of technology is the best fit for each configuration.

EPIA and the European Photovoltaic Technology Platform, therefore, joined the working group organised by EASE and EERA in charge of drafting the “European Energy Storage Technology Development Roadmap towards 2030”.

The scope of the cooperation is to ensure that all the storage functions that will enable an increased penetration of renewables in the electricity grid will be properly reflected in the storage roadmap.

E2B EI - *Energy Efficient Building European Initiative*

A similar approach has been adopted towards the Energy Efficient Building European Initiative (E2B EI). Contacts have been established to ensure that BIPV R&D activities will be complementary with the development of buildings envelope.