SET-Plan TWP PV Implementation Plan

Final Draft

Approved by TWG members

October 18th, 2017

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Introduction

The Integrated SET Plan

The Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy (Energy Union strategy) is built on the ambition to achieve a fundamental transformation of Europe's energy system in a cost-effective way. This will be achieved by moving to more sustainable, smarter, more flexible, more decentralized, more integrated, secure and competitive ways of delivering energy to consumers. Most importantly, meeting this ambition will require that energy producers and suppliers innovate in terms of energy production, transportation and services. As innovation is the basis to the Energy Union, it is vital to support researchers and companies at key stages in the development of new products and processes.

The Strategic Energy Technology Plan (SET Plan) as part of the Energy Union strategy is at the forefront of European energy technology policy. The integrated SET Plan will identify those strategic priorities and actions needed to accelerate the EU energy system transformation in a cost-effective way. Renewable technologies are at the heart of the new energy system with photovoltaic solar energy (PV) as a main pillar.

Consequently, PV contributes to two of ten SET Plan Key Actions, namely to develop highly performant renewables and to reduce the costs of key renewable technologies.

Photovoltaic solar energy (PV) technology

All major future energy scenarios forecast a key role for photovoltaic solar energy. PV has a huge global and European potential, making it an important building block for a secure and sustainable energy system. In several European countries PV already provides more than 5% of the annual electricity demand, a level originally anticipated to occur only after 2020. PV currently covers approximately 3% of total EU electricity demand. It has the potential to at least double its share by 2020 and to contribute some 15% in 2030. If achieved, this would result in a considerable contribution to the reduction of CO_2 emissions, since the carbon footprint of PV systems is at least 10 times lower than that of fossil fuel-based electricity, with no CO_2 emissions during operation. On a global level, PV now contributes almost 2% of total electricity and installations show rapid growth[1]. By the end of 2017, the total installed capacity is expected to be around 400 gigawatt-peak (GWp). It could reach 1 terawatt-peak (TWp = 1000 GWp) shortly after 2020, according to the annual market analysis of the European PV sector association Solar Power Europe[2]. This all, however, only represents a tiny fraction of the longer-term potential. In a recent paper in the high-impact journal Science, a group of scientists from Europe, USA and Japan describe pathways towards 10 TWp in 2030[3]. This level of global installations is needed to have real impact on achieving the climate targets agreed in Paris. It would require a tenfold increase of annual global installations and obviously pose a huge challenge, but also great economic opportunity. PV

[1] 2016 Snapshot of Global Photovoltaic Markets, IEA PVPV (2017)
[2] Global Market Outlook for Solar Power 2017-2021, Solar Power Europe (2017)
[3] *Terawatt-scale photovoltaics: trajectories and challenges*, Nancy M. Haegel et al., Science **356** (6334), 141-243 (2017).

deployment can be accelerated by further enhancing light-to-power conversion efficiency and reducing module and system prices as well as by removing energy system integration bottlenecks.

The PV industry has changed dramatically over the last few years. In Europe, the rapid growth of the PV market has not resulted in a similar growth of the production capacity of solar cells and modules. Europe has lost considerable market share in the past decade years. For instance in 2007, about 30% of the global photovoltaic modules manufacturing was done in Europe. In 2016 the share was about 3%[4]. The overall annual turnover of the European photovoltaic industry is estimated, currently, at EUR 5 billion. More than 60% of this figure goes to equipment manufacturing, 20% to inverter manufacturing, 9% to polysilicon production, and about 7% to cells and modules manufacturing[5]. These shares show that the EU PV industry is still well positioned in the upstream segments of the value chain, but is strongly challenged in the downstream parts. Importantly, Europe still has research institutes on PV that are able to maintain a leading position in the highly competitive global science and technology arena. This provides a crucial basis for any ambition to preserve or regain market share in the global PV sector.

Developing a strategy to build on the existing PV industrial and R&I base in Europe, with a view to re-launching cell and module manufacturing, is an urgent priority for three main reasons: 1. There is the concrete risk that once the *central segment* of the PV value chain is lost, soon after the *upstream segment* (i.e. equipment for manufacturing cells and modules) follows because of the continuous interaction and exchanges between the two industrial segments which generally requires logistic proximity; 2. All the analyses point to an ever larger role for photovoltaics in the future global energy system. Ensuring a strong EU position in this industry provides a source of economic growth and for a continued important role in innovative energy technologies, and, importantly, increased energy independence; 3.The 'Clean Energy for All Europeans' proposal announced a *Clean Energy Industrial Forum* to support the EU manufacturing industry (included the photovoltaic industry) to take advantage of the growth opportunities arising as part of the energy transition.

In this context, Europe must continue to invest in Research and Innovation and in industrial production and other activities over the full value chain to be able to play an active role and ensure again a strong industrial position. Managing innovation efficiently, maintaining technology leadership and ensuring a full commitment of industrial stakeholders require a coordinated approach at the European level.

This can happen only through the achievement of ambitious system, cost and performance targets, as well as regulatory and market design measures. System cost and performance are to a considerable extent interdependent and represent the actual drivers for the development of the sector. Indeed, increasing the efficiency of PV modules opens one path for reducing costs and allows for new industrial and market opportunities when accompanied by large scale manufacturing. As module costs account for around 50% of system costs, efforts need to be directed also at reducing the costs of Balance of System (BoS) technologies while introducing new functionalities for grid services. Furthermore, manufacturing of PV modules as building materials can develop to a world-wide market with huge opportunities for the European industry. Driven by policies towards Zero-Energy Buildings and subsequently Plus Energy Buildings (PEB), design and innovation with new

[4] Photovoltaics Report, Fraunhofer ISE, 12 July 2017
[5] Assessment of Photovoltaics, Final report, April 2017, EUR 27985 EN

Building Integrated Photovoltaic (BIPV) materials and concepts and combinations of energy efficient building materials with BIPV become essential parts of the development strategies of both the PV sector and the building sector. This calls for a multidisciplinary research and development program involving, among others, the PV manufacturing industry and the building materials industry as well as certification bodies. Breakthroughs in technology, applications and business models are required to transform today's BIPV niche market into a future mass market.

The combination of localized PV electricity, storage or local supply and demand management makes buildings the smallest unit of a smart grid of its own. Once the necessary technology and control mechanisms are developed, the step of linking multiple smart buildings will contribute to the widespread deployment of the smart grid technology. This requires the development of control systems for grid-feeding, self-consumption or local storage and standardization of the interoperability of such control systems.

The achievement of the targets will depend not only on technological advances, but also on non-technological factors such as economies of scale (i.e. resulting from an increase in produced and installed capacity), risk-finance for first-of-a-kind manufacturing pilot lines and demonstration of small, commercial scale PV power plants, the ability to take full advantage of the European Single Market, regulatory conditions, standards etc.

SET Plan strategic targets on PV

This Implementation Plan describes the technological and non-technological R&I activities that need to be implemented in order to achieve the strategic targets adopted in the SET-Plan Declaration of Intent (DoI) on PV[6], as agreed in December 2015 by the representatives of the European Commission services, representatives of the EU Member States, Iceland, Norway, Turkey and Switzerland (i.e. the SET-Plan Steering Group), and representatives of the SET-Plan stakeholders most directly involved in the PV sector[7].

The DoI recognises that, building on the Integrated Roadmap (IR) of the SET-Plan, public (EC and Member States/Regions) and private investment must focus on targeted R&I actions. The overarching goals are to re-build EU technological leadership in the PV sector by pursuing high-performance PV technologies and their integration in the EU energy system as well as bringing down the levelized cost of electricity from PV rapidly and in a sustainable manner to allow competition in electricity markets all over Europe. To achieve these goals, activities targeting improvements on PV system performance, cost reduction, sustainability and innovations have to be carried out. Advances on BIPV products are expected by joint efforts between the PV and the building sectors.

This will be achieved by:

1. Major advances in efficiency of established technologies (Crystalline Silicon and Thin Films) and new concepts:

    - Increase PV module efficiency by at least 20% by 2020 compared to 2015 levels;

[6] SET-Plan Declaration on Strategic Targets in the context of an Initiative for Global Leadership in Photovoltaics (PV), Strategic Energy Technologies Information System (SETIS), https://setis.ec.europa.eu

[7] The European Photovoltaic Technology Platform (PVTP), the European Construction Technology Platform (ECTP) and the EERA Joint Programme on Photovoltaics (EERA JP-PV).

- Increase PV module efficiency by at least 35% by 2030 compared to 2015, including with the introduction of novel PV technologies;

2. Reduction of the cost of key technologies:
   - Reduce turn-key system costs by at least 20% by 2020 as compared to 2015;
   - Reduce turn-key system costs by at least 50% by 2030 compared to 2015 with the introduction of novel, potentially very-high-efficiency PV technologies manufactured at large scale;
3. Further enhancement of lifetime, quality and sustainability and hence improving environmental performance:
   - Maintain proven system energy output per year at least 80% of initial level for 30 years by 2020 and for 35 years by 2025;
   - Minimize life-cycle environmental impact along the whole value chain of PV electricity generation, and increase recyclability of system components (in particular: of modules);
   - Perform focused research and apply & progress eco-design requirements in preparation of implementing measures supporting maximum energy yield (kWh/kWp) and lowest life-cycle environmental impact;
4. Enabling mass realization of "(near) Zero Energy Buildings" (NZEB) by Building-Integrated PV (BIPV) through the establishment of structural collaborative innovation efforts between the PV sector and key sectors from the building industry:
   - Develop BIPV elements, which at least include thermal insulation and water protection, to entirely replace roofs or facades and reduce their additional cost by 50% by 2020, and by 75% by 2030 compared to 2015 levels, including with flexibility in the production process;
   - Recognize the importance of aesthetics in the activities of the implementation of NZEB;
5. Major advances in manufacturing and installation:
   - Make available GW-scale manufacturing technologies that reach productivity and cost targets consistent with the capital cost targets for PV systems;
   - Develop PV module and system design concepts that enable fast and highly automated installation, to reduce the installation costs of both ground-mounted arrays and PV building renovation solutions, by 2020.

Temporary Working Group

In line with the common principles guiding the preparation of the Implementation Plans within the Integrated SET Plan, a Temporary Working Group (TWG) on PV was set up. It is composed of 30 members forming a balanced group of SET Plan countries, Stakeholders and EC, see annex II.

- SET Plan countries are committed to use their energy R&I national programmes and policies to implement some of the R&I activities that will be selected; and are preferably interested in developing and pursuing joint research with other countries. Country representatives in the TWG PV are government representatives, or nominated by their governments.
- Stakeholders are experts from ETIP[8] PV, EERA[9] and industry not organized in the ETIP.
- The EC facilitates and supports the TWG as needed in agreement with the Chair and Co-Chair.

The nomination of the Chair and Co-chair took place before the first WG meeting on invitation of the EC:

- Chair of the TWG PV: Christoph Hünnekes, Project Management Jülich, Energy System: Renewable Energies / Power Plant Technology, Head of Photovoltaics, Forschungszentrum Jülich GmbH, DE-Jülich
- Co-Chair of the TWG PV: Wim Sinke, Co-chairman European Technology and Innovation Platform Photovoltaics, ECN Solar Energy, NL-Petten
- Supported by EC: Fabio Belloni, Directorate-General for Research & Innovation, Directorate G – Energy, Unit G.3 , BE-Brussels

[8] European Technology & Innovation Platform
[9] European Energy Research Alliance

Priority technology actions (R&I Activities)

The process to define the priority technology actions (R&I Activities)

The core of the Implementation Plan is a selection of R&I activities to be carried out by the various actors (SET Plan countries, stakeholders and, within its mandate, the EC) in order to achieve the targets set in the DoI.

Since its installation in January 2017, the work of the TWG was mainly on the definition of priority R&I activities. A kick-off meeting of the TWG was held in Brussels on 25 January 2017. For the definition of R&I activities, a bottom-up approach was agreed upon. Therefore, a template was sent out to all TWG members after the meeting to collect topics for a long-list of proposals. Until mid-March a set of 53 topics all in accordance with the DoI was compiled, and being characterized by a technical description, concrete targets and priorities.

Following this step, the chair / co-chair of the TWG provided a proposal for a Short-list of 6 combined main activities by grouping the 53 individual topics. Until end of May the definition of these activities was discussed and refined within the TWG.

For each of the 6 activities a subgroup was established which elaborated a draft of the description of each R&I activity. The rapporteurs of the subgroups (see below) handled in first versions of the descriptions by mid-June which were commented by the chair / co-chair. Final drafts were received by mid-July. During this phase multiple phone conferences within the subgroups and between chair / co-chair and the EC coordinating officer took place.

Some of the activities have well identified potential participants; however, this is not an exhaustive list. All activities are open to the participation of other interested entities.

TWG PV subgroups and lead:

No	Subgroup	Lead
1	PV for BIPV and similar applications	Otto Bernsen (NL - Netherlands Enterprise Agency)
2	Technologies for Silicon Solar Cells and Modules with higher quality	İlknur Yilmaz (TR - TUBITAK), supported by Prof. Rasit Turan[10] and Emiliano Perezagua (ES - Consultores de Energía Fotovoltica SL)
3	New technologies & materials	Stefan Janz and Simon Philipps (both EU - EERA PV and DE - FhG-ISE)
4	Development of PV power plants and diagnostic	Achim Woyte (BE - 3E) and George E. Georghiou (CY – University of Cyprus)
5	Manufacturing technologies (for cSi and thin film)	Bernhard Dimmler (DE - Manz AG) and Philippe Malbranche (FR - INES)
6	Cross-sectoral research at lower TRL[11]	Otto Bernsen (NL - Netherlands Enterprise Agency)

[10] GUNAM - Center for Solar Energy Research and Applications
[11] Technology Readyness Level

The R&I Activities

The TWG elaborated a set of 6 technology-related priority activities for the future development of PV technologies and applications in Europe. For each priority, ongoing R&I activities (conducted at national and/or at European level and/or by industry) have been identified which already support the strategic targets. Additional R&I activities are considered important as the global PV industry is currently developing rapidly technologically as well as economically.

The 6 R&I activities reflect the prioritised strategic targets defined in the DoI.

1. PV for BIPV and similar applications

   The R&I activity on BIPV aims at developing a market pull approach for innovative and integrated PV solutions that will allow a faster market uptake of new PV technologies and a more intensive and multi-functional use of the available surface area in Europe, including quality and reliability. This requires a multidisciplinary approach and close collaboration between the PV/BIPV and building sectors.

   On the one hand, for BIPV it seems likely that thin film technologies (especially CIGS) are well suited. Therefore, a combined development of thin-film PV and BIPV is suggested. On the other hand, BIPV solutions based on other PV technologies can also offer attractive solutions. Sub-activities cover bifacial applications and PV installations on roads & waterways.

2. Technologies for silicon solar cells and modules with higher quality

   Wafer-based silicon (cSi) technologies have the largest market share (>90%) in the worldwide solar PV sector. The main objective of this Activity is to develop and implement advanced cSi PV technologies for high-quality, high-performance cells (≥24%) and modules in high-throughput industrial manufacturing processes, including (for the PV sector) new materials and production equipment. These products will serve as differentiator for the European PV industry by means of significant efficiency benefits and better performance related to sustainability aspects and recyclability of modules (PV Ecolabel, Ecodesign and Energy labels). Through this, the European PV industry will be able to strengthen its global position.

3. New technologies & materials

   Crystalline silicon based solar cells as well as some thin film technologies are gradually reaching their theoretical efficiency limit. The most promising approach (at least on the short and medium term) to go beyond this limit are tandem technologies. Concrete options are III/V-semiconductor or perovskite top cells on silicon bottom cells. Another option is a stack of two thin-film cells. A third route is the development of cost-effective concentrating PV (CPV).

   The aim of this activity is to bring these technologies to an economically feasible level. Therefore the cell processing needs to be scaled-up on an industrial level and the cost needs to be reduced. New materials and the combination of two cell technologies need new interlayer development. Also the stability needs to be enhanced (or maintained if already sufficient). In the end the environmental impact of these new materials needs to be evaluated including quality and reliability.

4. Development of PV power plants and diagnostics

   The aim of this activity is to develop and demonstrate business models and streamline the processes for effective operation and maintenance of residential and small commercial plants in order to keep the plant performance and availability high over the expected lifetime. Especially advanced monitoring is essential. Due to incompatibility and the accompanying extra costs this is often not done according to good industry practices.

   Aspects of energy system integration are included, but as an integral part of the PV system.

5. Manufacturing technologies (for cSi and thin film)

   Further reduction of system and generation costs (LCoE) for silicon wafer based PV and thin film technologies is strongly supported by the implementation of high-throughput, high yield industrial manufacturing technology. This includes production equipment (Capital Expenditure; CAPEX) and material (Bill of Materials; BOM) costs as well as product quality (efficiency and performance). Advances in this field will strengthen the European manufacturing industry. The introduction of new materials and cell/module designs enforces advances in the field of manufacturing technologies, including the introduction of Industry4.0 (“smart factory”) in PV, and will also strengthen the European manufacturing equipment industry.

6. Cross-sectoral research at lower TRL

   With respect to high level R&D, European research labs are still the leading institutions worldwide. A closer cooperation of these labs could help maintaining this position in order to support European industry with cutting edge research results.

   On a topical level this activity covers all the other activities described above, with a focus on the low TRL-parts of the total R&I programs.

Details of the R&I activities are attached as Annex I.

Summary and next steps

The Temporary Working Group on PV, composed by representatives of interested SET Plan countries and relevant stakeholders, representing industry and academia, has identified the priority research and innovation activities (of both technological and non-technological nature) included in the present Implementation Plan. The work has progressed in the course of 2017.

The priority R&I activities are considered to be essential for achieving the corresponding SET Plan targets contained in the Declaration of Intent on PV. Across the proposed actions, the overall volume of investment to be mobilised has so far been identified in broadly 530 M€, with the main contribution expected from the SET Plan countries involved, then from industry, finally from the Horizon 2020 Framework Programme. Some of the actions are already running.

The emphasis has mainly been put on demonstration activities. Nonetheless, research at lower TRL has also been targeted where appropriate, especially under Activities no. 3 and 6. Non- technological aspects have also been addressed, especially within Activities no. 1, 4 and 6. In particular, deployment of BIPV products and PV plants through market uptake actions has been considered under Activities no. 1 and 4, respectively.

The activities proposed have reached different levels of maturity in terms of concreteness, partnership and financing. There is therefore a significant need for further development of the actions. Also, further investments, funding sources and financial instruments[12] will be needed to fully achieve the DoI targets, especially in connection to demonstration and deployment of technologies. The execution of IPs is supposed to be a continuous process, however. Continued work is expected in the next phase to further define financial planning and full commitment of the intended actors.

With the production of this IP and after its endorsement by the SET Plan Steering Group, the mission of the PV TWG is completed. A new structure needed for the follow up of the effective execution of the IP is expected to be put in place.

The EC intends to facilitate through a Coordination and Support Action (CSA) the coordination activities needed for the execution of the IPs[13]. The proposed consortium should count with the participation of research organisations and/or companies (industry) committed in principle to execute all or some of the R&I activities specified in the corresponding IP as endorsed by the SET Plan Steering Group.

In order to keep the momentum and ensure the delivery of the work so far planned, meetings will be organised as necessary.

[12] At EU level, instruments such as *InnovFin Energy Demonstration Projects* and the future *Innovation Fund* are obvious potential sources of finance.
[13] See topic "LC-SC3-JA-2-2018: Support to the realization of the Implementation Plans of the SET Plan" of the Horizon 2020 Work Programme 2018-2020 - Secure, clean and efficient energy.

Annex I – R&I Activities

R&I Activity n. 1 - PV for BIPV and similar applications

PV for BIPV and similar applications (building integrated PV includes here the integration of PV into the infrastructure)	
Targets: Cost reduction of new PV integrated applications through technological and production related progress as well as upscaling national niche markets (reduce additional cost by 50% by 2020, and by 75% by 2030 compared to 2015 levels) and thereby accelerating the energy transition. Taking short term measures can still contribute to the goals already stated in the SET plan for 2020 and an economically viable GW size European market in 2030.	**Monitoring mechanism**: Compare total market size and application prices for integrated PV at the start (2017) and finish (2020) for each PMC (product market combination). Estimate added surface otherwise unused for PV. Cost reduction of integrated PV solution by square meter. Estimate progress of the learning curve in TRL levels of technology.

Description: The main policy drivers behind BIPV market growth in Europe is the fact that, buildings being responsible for more than one third of the final energy consumption of EU, there is an urgent need to make the EU building stock more energy efficient and smarter to accomplish the EU Energy and climate objectives[14]. A number of key requirements should be addressed by the supply chain to fully exploit the potential: flexibility in design and aesthetics considerations, demonstration of long-term reliability of the technology, compliance with legal regulations and cost effectiveness.

This activity aims at developing a complementary market pull approach to the technology development for innovative, multidisciplinary BIPV solutions in the built environment that will allow a faster market uptake of new integrated PV technologies and a more intensive and multi-functional use of the available surface area in Europe, whilst enhancing quality, reliability and live span of the BIPV products and reducing costs.

The added functionality of thin film technologies (such as CIGS, amorphous silicon, organic solar cells and possibly, in the longer term, perovskites) is well suited for specific market segments where flexible and semi-transparent solar cells are needed. Therefore, a combined development of thin film and BIPV is suggested but not exclusively as crystalline and hybrid technologies may still be competitive as well. The continued R&D effort into efficiency and quality improvement also needs to be paired with the integration issues of solar cells and modules into the built environment. Besides this R&D agenda, short term costs reductions will also have to be realized by re-organizing the value chain and scaling up local customized production by harmonizing markets at the finished end products level.

Thus, this activity underpins the strategic target of mass realization of "(near) Zero Energy Buildings" through the establishment of structural collaborative innovation efforts between the PV sector and key sectors from the building industry, namely the development of BIPV elements, which at least include thermal insulation and water protection, to entirely introduce advanced solar building skins, including with flexibility in the production process while recognizing the importance of aesthetics in the activities of the implementation. The interconnection to areas such as e-mobility, Internet of things (in buildings and Cities), circular economy, etc. is important to develop new business models for BIPV within the smart city approach. This underlines the interface with other priority areas of the SET Plan, as well as with the Implementation Plan for

[14] Proposal amending Directive 2010/31/EU on the energy performance of buildings COM/2016/0765 final - 2016/0381 (COD)

Energy Efficiency.

Additionally, PV integration into large infrastructural constructions like roads, railways and waterways will be covered which seem to hold a new and so far undiscovered potential.

Supporting the development of a European BIPV/PIPV[15] value chain is a top priority from the technical, financial and political points of view. The offer of innovation from the R&D institutions (push) should be matched by actions to support the demand by the end-users (pull) starting with the development of industrial prototyping facilities jointly run by industries and research institutions.

TRL: TRL 3 (experimental proof of concept) to TRL 7 (system prototype demonstration in operational environment) - depending on technology and application[16]

Total budget required: Generic PV funding budgets in the MS's already cover the higher cell and module efficiencies and some of the quality issues (see as well activities 2, 3, and 5). Specific R&D into the integration topics and production technologies, related to specific market segments, would require around 5 million €/y to reach critical mass and EU cooperation.

For joint demonstration and feasibility projects close to the market one would need additional 2-5 mil. €/y in total.

Expected deliverables	**Timelines**
Action lines: 1. EU market alignment for large scale BIPV deployment. (goal GW market before 2030 and cost reduction in the value chain) 2. Joint R&D (goal cost reduction and customized high quality integrated products). 3. Organise specific national workshops, based on the close collaboration with national stakeholders and industries, as well as with the SET Plan Committee representatives of the various European countries.	1. starting Q4 / 2019 and follow-up at least until 2025 2. 2017 to 2022 3. from 2018 on

Party / Parties *(countries / stakeholders / EU)	**Implementation instruments**	**Indicative financing contribution**
running activities		
EU ETIP PV BIPV Working Group	workshops	combination of EU and national funding mechanisms
IEA PVPS Task15 – Austria, Belgium, Denmark, France, (Germany), Italy, the Netherlands, Norway, Spain, Sweden, Switzerland (and Canada, Japan, Korea)	R&I activity on international level: The objective of Task 15 is to create an enabling framework to accelerate the penetration of BIPV products in the global market of renewables, resulting in an equal playing	Initially 190 PM foreseen (approx. 1.7 mill. €, mostly financed by contributing countries)

[15] PIPV: Product Integrated PV

[16] Extension into TRL 8 cannot be covered in many countries by the funding agencies with some exceptions.

	field for BIPV products and regular building envelope components, respecting mandatory issues, aesthetic issues, reliability and financial issues	
Germany, Netherlands and other Member States and regions	R&I on national level	> 4 mill. €/y
Netherlands	market oriented demonstration and short term product development[17]	40.3 mill. €/y plus 50 mill. €/y
Solar ERA-Net participants	joint R&I activities between SET Plan countries (projects like “BIPV-pod”, “PVme”)	> 2 mill. €/y
Outlook on planned activities		
France, Germany, Italy, Netherland, Turkey and other Member States and regions: support for industrial organizations and joint projects between industry and research institutes	R&I on national level like French initiative dedicated to light weight and flexible PV modules, Italian Flagship Programme: “Italian BIPV/PIPV value chain” partly based on “Mission Innovation” targets	> 15 mill. €/y
Solar ERA-Net participants	joint R&I activities between SET Plan countries	> 2 mill €/y

[17] both for NLD - generic for RES

R&I Activity n. 2 - Technologies for silicon solar cells and modules with higher quality

Technologies for silicon solar cells and modules with higher quality	
Targets: Bring down the Levelised Cost of Electricity (LCoE), by: • increasing PV module efficiency by at least 20% by 2020 compared to 2015 levels; • increasing PV module efficiency by at least 35% by 2030 compared to 2015 levels; • improving product quality, reliability, stability and lifetime (the latter to 30 yrs in 2023 and 40 yrs in 2030); • improving (environmental) sustainability and bankability; • Improving applicability through better aesthetics, form freedom, function integration, and shade tolerance.	**Monitoring mechanism**: monitoring will be done by funding agency.

Description: Wafer-based silicon (cSi) technologies*) have the largest market share (>90%) in the worldwide solar PV sector, making this a very important activity. The main objective of this Activity is to develop and implement advanced cSi PV technologies for high-performance cells (≥24%) and modules in high-throughput industrial manufacturing processes, including (for the sector) new materials and production equipment. These high-quality modules will serve as differentiator for the European PV industry by means of significant efficiency benefits and better performance related to sustainability aspects and recyclability of modules (PV Ecolabel, Ecodesign and Energy labels). Through this, the European PV industry will be able to strengthen its global position.

*) *cSi includes PERX (PERC, PERT and PERL) and back-contact (IBC) mono- and bifacial designs as well as heterojunction technologies (HJT); all with advanced passivation schemes.*

TRL: 3 -7

Total budget required: The overall PV funding budget in the participating countries Germany and the Netherlands varies between 60 and 90 million euros per year. There is no dedicated budget for cSi PV technologies but based on experience of the last years, approximately up to 70% of the total PV budget was used for funding in this part of sector.

Expected deliverables	**Timeline**
• Cell efficiency 24% in industrial environment (with PERC).	5 years
• Module efficiency >22% with a module lifetime of >30 yrs at >80% power output.	5 years
• Demonstrated industrial processes for passivated contacts for cells with efficiencies >24% and >90% bifaciality.	5 years

Party / Parties (countries / stakeholders / EU)	**Implementation instruments**	**Indicative financing contribution**
running activities		
Silicon purification - Silicio FerroSolar, Aurinka PV, IES-UPM (Spain)	National funding and industry resources	tbd
Crystallization and wafering: multiple R&D projects in different Member States and Regions, beside others	National funding and industry resources	> 10 mill. €/y
- „Inno-Si": development of innovative silicon crystallization processes (PVA Crystal Growing Systems GmbH, Fraunhofer-Center für Silizium-Photovoltaik CSP)	National funding and industry resources	
- "EpiPower": epitaxially grown wafers (NexWafe GmbH, Fraunhofer-Center für Solar Energiesysteme ISE, Singulus Technologies AG, centrotherm clean solutions GmbH & Co. KG)		
Cell technologies: multiple R&D projects in different Member States and Regions, beside others		
- AMPERE Project (HJT and bifacial Silicon solar cells, module technology, pilot plant)[18]	national/European funding and industry resources	~ 26.6 mill. € in total
- Italian Flagship Programme: "Innovative Technologies for Modern Utility-Scale PV – part a"	national/European funding and industry resources	t.b.d.[19]
- support for industrial organizations and joint projects between industry and research institutes	National funding and industry resources	> 15.0 mill. €/y
Module technologies: ERC Project: Multi- field and multi-scale Computational Approach to design and durability of Photovoltaic Modules[20]	European funding	€1.5M over 5 years (ends in 2018)
multiple R&D projects in different Member States and Regions, beside others	National funding and industry resources	> 5.0 mill. €/y
- Dutch TKI Urban Energy program		
- Spanish and German activities		

[18] http://cordis.europa.eu/project/rcn/209763_en.html
[19] total funds for Flagship Programme (part a, b & c) ~ 100 mill. € over 5 years based on Mission Innovation targets
[20] http://musam.imtlucca.it/CA2PVM.html

Outlook on planned activities		
France, Germany, Italy, Netherland, Turkey and other Member States and regions: support for industrial organizations and joint projects between industry and research institutes on **Cell technologies:** - Evolutionary development of PERC technologies Development of HJT technologies with economic viability - Development of IBC technologies with economic viability - Identifying and demonstrating industrially feasible cell concepts and production processes and equipment for passivated contacts for both polarities, to further improve PERX, HJT and IBC technologies	National funding and industry resources	prospective funding - 18 mill. € - 10 mill. € - 15 mill. €
Module Technologies Identifying and demonstrating industrially feasible and reliable contact and module technologies for highest efficiency cSi cells with passivated contacts, a module efficiency of >22 % with <80% degradation over a lifetime of >35 yrs.	National funding and industry resources.	tbd
European quality/sustainability "label or method" (Ecofriendly processes and products including materials) - CENER (Spain), Fraunhofer (Germany) and others	National funding and industry resources.	tbd

R&I Activity n. 3 - New Technologies & Materials

New multi-junction PV technologies for highest efficiencies at reasonable costs

Targets: R&I Activity will help to achieve all 5 strategic targets of the DoI but mainly target: "Major advances in efficiency of established technologies and new concepts". More specific: to achieve efficiency targets above limits of existing individual PV technologies towards 35% (in 2-5 yrs) and 40% (in 5-10 yrs) with tandem structures of cSi, Thin Films (TF) and concentrating PV technologies.	**Monitoring mechanism**: funding agencies and stakeholder groups will monitor progress towards the targets.

Description: The dominant crystalline silicon wafer solar cell is converging to its theoretical efficiency limit. As efficiency improvement and cost reduction must proceed for successful power market development, approaches which can meet these needs are inevitable. The most promising one to further improve efficiencies are multi-junction (mj) technologies with Si or CIGS as bottom absorbers and with III/V semiconductors, perovskite, CIGS or other high-bandgap top absorbers, and the already available multi-junction technology concentrating photovoltaics (CPV). The aim of this activity is to raise these technologies to an industrial level. Therefore new ways of absorber layer fabrication, interface design and interconnection of the sub-cells have to be developed. Focus should be on the development and application of new materials, new cell and module concepts and of production equipment and related production processes. Furthermore quality and reliability needs have to be fulfilled and the environmental impact needs to be evaluated. The energy yield of these technologies in real conditions should also be clearly stated.

TRL: 3 - 7

Total budget required: Budgets required for each main topic is in the range of 15 – 50 Mio. €. Participation and collaboration of competing concepts and production equipment / processes will in most cases be an efficient solution bringing synergies. A proper handling of IP is important.

Expected deliverables	Timeline
For multi-junction devices on Si or CIGS:	
• Stable (years) efficiencies (>30%) for perovskite on Si / CIGS mj-cells	• 2 – 5 years
• New methods / tools for economic III-V absorber deposition and transfer	• 2 – 5 years
• Low-cost deposition of GaP on Si mj-cells	• 5 – 10 years
• Wide gap top cells (Perovskites, CIGS) (> 20%) based on economically viable production processes.	• 5 - 10 years
• Adaptation of Si / CIGS bottom cell	• 2 – 5 years
• Monolithic interconnection methods	• 2 – 5 years
• Life cycle analysis for whole fabrication route	• 2 – 3 years
• Demonstrations of economic tandem cells on industrial level	• 3 – 7 years
• Sustainable module solutions for multi-junction solar cells	• 5 - 10 years
• Energy yield in real conditions (spectrum and temperature variations)	• 2 – 5 years
• Advanced characterization and modelling methods / tools dedicated to multi-junction devices	• 2 – 5 years
For CPV:	
• New methods / tools for economic III-V absorber deposition and transfer	• 2 – 5 years
• High performance module with >40 % efficiency	• 2 – 5 years
• Life cycle analysis for whole fabrication route	• 2 – 3 years
• Energy yield in real conditions	• 2 – 5 years

Parties (countries / stakeholders / EU)	**Implementation instruments**	**Indicative financing contribution**
running activities		
Horizon 2020 projects CPV Match[21] - Concentrating Photovoltaic modules using advanced technologies and cells for highest efficiencies CHEOPS[22] - Production technology to achieve low Cost and Highly Efficient phOtovoltaic Perovskite Solar cells	European funding	~ 4.5 mill. € from 2015 to 2019 ~ 5.0 mill. € from 2016 to 2019
France, Germany, Italy, Spain and other Member States and regions: support for industrial organizations and joint projects between industry and research institutes on	National funding and industry resources	> 2.5 million € total
- multi-junction devices on Si	beside others ***Flagship project "PersiST"*:** development of perovskite/silicon tandem solar cells on cell level; improvement of efficiency, stability, eco-compatibility	
- CPV	beside others **Flagship project "CPVMod"**: development along whole value chain and demonstration especially in sunny regions to push acceptability	
Outlook on possible funding topics		
Italian Flagship Programme: "*Innovative Technologies for Modern Utility-Scale PV – part b"* Confirmed partners 3Sun, Enel Green Power, Applied Materials, ENEA, CNR, MIBSolar, CHOSE, multiple Italian universities, ..	national/European funding and industry resources - Tandem solar cells obtained by combining crystalline Silicon with thin film solar cells: Perovskite/Silicon,Wide-gap CIGS/Silicon, GaP/Si tandem cells - Innovative solar cell architectures for high conversion efficiency including back contact schemes and multi-junction cells for high concentration PV systems. - bifacial solar cells - Advanced characterization and modelling for multi-junction cells	tbd (total funds for Flagship Programme (part a, b & c) ~ 100 mill. € over 5 years based on Mission Innovation targets)

[21] https://cpvmatch.eu/
[22] http://www.cheops-project.eu

multi-junction devices on Si *confirmed partners* - TKI Urban Energy, ECN.TNO, Solliance, Radboud Uni. Nijmegen, Tempress - FhG-ISE, Uni Freiburg - IES UPM, CIEMAT, DHV Technologies - IPVF, INES *further possible partners* - HZB, Merck, Heraeus, ISFH, Evonik, Meyer&Burger, Singulus, EPFL/CSEM	Project with national / European funding and industry resources - Stable (years) efficiencies (>28%) for perovskite on Si mj-cells - New methods / tools for economic III-V absorber deposition and transfer - Wide gag CIGS top cell - Adaptation of Si bottom cell - Monolithic interconnection methods - LCA for whole fabrication route - Demonstrations of economic cells on industrial level - Sustainable module solutions for multi-junction solar cells - Advanced characterization and modelling for multi-junction cells	tbd
CPV *confirmed partners* - FhG-ISE - IES UPM, BSQ Solar, Solar Added Value, DHV Technologies, Tecnalia, CENER *further possible partners* - Azur Space Solar Power, Orafol Fresnel Optics	Project with national / European funding and industry resources - Development of new methods / tools for economic III-V absorber deposition and transfer - High performance module with >40 % efficiency - Life cycle analysis for whole fabrication route	tbd
All thin film multi-junctions *confirmed partners* EMPA/FLISOM, ZSW, IMEC, Manz CIGS	Project with national / European funding and industry resources Already existing consortium in horizon2020 “sharc25” as follow up project on CIGS-Perovskites and others; all expertise is already there on a high level - R&D on CIGS & Perovskite - R&D on CIGS & other thin film compound - Sustainable mj devices (resources, stability, LCA ...) - Manufacturability and economic assessment	~ 10 mill.€ in total and 4.5 mill. € funding

Member States and regions: support for industrial organizations and joint projects between industry and research institutes like	National funding and industry resources	
Turkish national support for new generation solar cell systems by means of “1003 - Primary Subjects R&D Funding Program”	Research projects for the high efficiency, low cost, long life new generation solar cell system development would be supported (artificial leaf, perovskite and quantum dot)	tbd
and “1511 - Research & Technology Development and Innovation Program”	Support will be given to production and demonstration of new generation solar cells via two different calls (incl. BIPV)	tbd

R&I Activity n. 4 - Operation and diagnosis of photovoltaic plants

Operation and diagnosis of photovoltaic plants	
Targets: This Activity contributes mainly to Targets 3 of the Declaration of Intent: "Further enhancement of lifetime, quality and sustainability", by: On PV plant level, achieve common annual performance ratio (PR) including periods of unavailability and after correction for expected degradation in the field: 82% PR for residential and small commercial plants and 87% for other plants installed in 2020; and 85% for residential and small commercial plants and 90% for other plants installed in 2025. Today average PR values are around 78% for residential and 81% for the larger plants. The given targets are for a Western European moderate climate and accordingly lower or higher in warmer or colder regions, respectively.	**Monitoring mechanism**: Monitor national medians of annual PR of operational plants for year 1 and year 5 (end of warranty) of operation per member state and PV market segment.

Description:

The aim of this activity is to develop and demonstrate technical solutions, business processes and business models that can support high plant performance, availability and income at reasonable costs for advanced monitoring, operations and maintenance (O&M) over the expected lifetime of the PV plant. The three main drivers of Levelised Cost of Electricity (LCoE) reduction in practice are advanced monitoring, qualification of contractors for engineering, procurement and construction (EPC), and product testing. Today, in the segments of large commercial and utility scale plants above 500 kW, advanced monitoring is increasingly applied; with a large market potential world-wide. In the segments of residential up to medium-size commercial plants, only basic monitoring is on hand but advanced monitoring is barely available today. Specific objectives of this action are:

- advanced and automated functions for data analysis, fault detection, diagnosis, maintenance planning and/or reporting;
- interoperability, standardization and auto-configuration of sensors, data acquisition, inverters and communication systems within PV plants and between PV plants and central monitoring systems (Industry 4.0/internet of Things);
- easy-to-understand business models with quality KPIs for monitoring, O&M and asset management of residential up to medium-size commercial plants which transparently return the net benefit of better operations to the stakeholders involved.

Beyond the technical performance, income in future will increasingly be determined through the market value of the electricity in a given market environment, which is still member-state specific. Value may be created through aggregation and sales on spot or ancillary service markets or through energy management at the prosumer-side of the energy meter. In this respect, specific objectives are:

- Interoperability in terms of control and bidirectional communication between PV plants among each other, distributed energy management systems, and central control systems;
- Inclusion of aggregation and energy management into business models and KPIs for monitoring, PV plant O&M and asset management as listed above.

TRL:

- Advanced automatic functions for monitoring: target TRL 6-7 (Industrial research & demonstration)
- Interoperability, standardization and auto-configuration of PV plant components; Interoperability in terms of control and bidirectional communication between plants and

central systems: target TRL 7-9 (Industrial research & demonstration / Innovation & market uptake)

- easy-to-understand business models for monitoring, O&M and asset management of residential up to medium-size commercial plants; Inclusion of aggregation and energy management into business models and KPIs: target TRL 9 (Innovation & market uptake)

Total budget required: €60 million

Expected deliverables	**Timeline**
1. Industry-driven demonstration projects targeting advanced automatic functions for monitoring covering the different market segments (few projects per target with large impact) showing, for the first years of operation, a 5% PR increase over plants installed in 2017;	2022
2. Industry-driven demonstration projects targeting interoperability, standardisation and auto-configuration of PV plant components (few projects per target with large impact), reducing costs for monitoring compared to 2017 by 20%;	2022
3. Industry driven market uptake projects, with one or more of the following targets (several smaller projects per target):	
3.1. interoperability, standardisation and auto-configuration of PV plant components; reducing costs for monitoring compared to 2017 by 20%;	2022
3.2. interoperability in terms of control and bidirectional communication between plants and central systems; reduce costs for technically enabling market access and aggregation below 1% of LCOE.	2022
3.3. easy-to-understand business models for monitoring, O&M and asset management of residential up to medium-size commercial plants; 50% of new plants in this segment are followed up actively.	2022
3.4. the inclusion of aggregation and energy management into business models and KPIs; KPIs include a parameter reflecting the power value of the generated electricity.	2022

Party / Parties *(countries / stakeholders / EU)	**Implementation instruments**	**Indicative financing contribution**
Outlook on future topics		
1. Advanced automatic monitoring functions: industry (O&M services, monitoring, sensors, modules, inverters), MS & EU	1. National level (mixed funding public-private), joint R&I activities between SET Plan countries (EUREKA-EUROGIA, ERA-NET Cofund), EU level (Framework Program)	1. €20 million • Industry: 30-60% • Public: 70-40%
2. Interoperability, standardization and auto-configuration of PV plant components: industry (monitoring, sensors, inverters), MS & EU	2. Joint R&I activities between SET Plan countries (EUREKA-EUROGIA, ERA-NET Cofund), EU level (Framework Program, Interreg)	2. €20 million • Industry: 30-60% • Public: 70-40%

3. Market uptake 3.1. Interoperability, standardisation and auto-configuration of PV plant components: industry (monitoring, sensors, inverters, industry associations), MS & EU 3.2. Interoperability in terms of control: industry: (energy suppliers or aggregators, monitoring, PV O&M, PV asset managers) 3.3. Easy-to-understand business models for monitoring, O&M and asset management of residential up to medium-size commercial plants: industry (energy service companies, PV asset managers) (private & public sector), MS & EU 3.4. Aggregation and energy management: industry (energy suppliers or aggregators, monitoring, PV O&M and installation sector, PV asset managers, industry associations), MS & EU	3. EU level (Framework Programme, Interreg) due to the European dimension of unteroperability and standardization; Possibly Interreg for a Flagship project	3. €20 million • Industry: 30-60% • Public: 70-40%
flagship project: A pilot for O&M and asset management of residential up to medium-size commercial plants built on one or several easy-to-understand business models and accessible monitoring solutions; showing how PR for this segment can be increased by 5 to 10% through professional operations. Parties: industry (energy service companies, PV asset managers, PV O&M services, monitoring software); public sector, e.g., social housing, municipalities, public energy suppliers; MS & EU		tbd
Member States and regions: support for industrial organizations and joint projects between industry and research institutes like Italian Flagship Programme: "Innovative Technologies for Modern Utility-Scale PV – part c" partners: RSE, ENEA, Eurac, CNR, CHOSE, multiple Italian Universities	national/European funding and industry resources • Energy Storage for utility-scale PV plants • Innovative Power and Control Electronics • Technologies for O&M/upgrade/decommissioning of existing utility-scale PV plants • Energy dispatch optimisation	tbd (total funds for Flagship Programme (part a,b &c) ~ 100 mill € over 5 years based on Mission Innovation targets)

and related issues • PV integration in small and medium grids and management of different energy sources • PV as ancillary service to the grid	

R&I Activity n. 5 - Manufacturing technologies

Manufacturing technologies for silicon and thin-film PV

Targets: Bring down the Levelised Cost of Electricity (LCoE) through reduction of the module manufacturing cost (of ownership; CoO) by 25% in 5 yrs, and 40% in 10 yrs. This is done by reducing:

- equipment cost by 30% in 5 yrs, and 50% in 10 yrs;
- material cost by 20% in 5 yrs, and 40% in 10 yrs.

Monitoring mechanism: regular reporting by project partners related to set quantitative technical milestones as deliverables and regular assessment by high level industry, and professional supervisors, funding agency

Description: production equipment (Capital Expenditure; CAPEX) and material (Bill of Materials; BOM) costs and product quality (efficiency and performance) directly influence manufacturing costs and LCoE. A further reduction of manufacturing costs for crystalline silicon (cSi) and thin-film PV modules relies on the implementation of highly productive manufacturing equipment and processes (CAPEX) and reduced materials expenses (BOM). The introduction of new materials and cell/module designs enforces advances in the field of manufacturing technologies (including the introduction of Industry4.0 in PV) and will also strengthen the European manufacturing equipment industry. Achieving the main targets requires research and innovation (R&I) in the following fields and topics:

Material cost (BOM) reductions:

- use of input materials for cell/module production with reduced carbon footprint and (required) purity and enhanced availability of resources (including the development of alternatives);
- reduction of the amount of input materials needed by reduced thicknesses and higher material usage (material yield and recycling), and introduction of better materials.

Manufacturing equipment cost (CAPEX) reductions:

- increase of the productivity of large scale manufacturing equipment and processing by enhancement of:
  - throughput (wafers/time, module area/time);
  - yield (process and quality control, including by Industry4.0 features, such as self-learning);
  - availability (optimization of uptime and service time, a.o. by self-learning);
- replacing batch by in-line processing and parallelization of processing, handling and quality control;
- equipment for increased product size: thin-film modules to 1.5 - 2.5 m^2; optional: increased cSi wafer size or reduced wafer thickness;
- improved in-situ and off-line quality control;
- flexibility of back-end process for automated production for specialized modules (BIPV, consumer, automotive etc. products) with input from Activity 1.

Process and equipment alternatives:

- alternative processes and equipment for reduced CAPEX and BOM (in-line, non-vacuum, roll-to-roll, printing and laser-supported techniques, hybrid technologies);
- equipment and processes for new sealing concepts (further exploration of thermoplasts and other materials, smart coatings to replace front glass lamination, adaption to special climatic conditions and applications (integrated solutions).

TRL: depending on topic and present status R&I work could be advanced research (AR) but will mainly be industrial research & demonstration & innovation (iR&D&I) for improving actually used and next generation equipment, status and further increase of scaling. The TRL levels at start are 6-7 (with applied R&I at TRL 3-5), TRL levels at end 8-9 (with applied R&I at TRL 5-7).

Total budget required: industry-relevant prototype equipment is needed for demonstration and qualification, to fulfil the needs for rapid transfer to large scale manufacturing. Therefore the budgets required for each equipment topic is in the range of 10 – 50 Mio. EUR. R&I on materials and processes will have lower budget needs in first level R&I. Pilot lines in the range 50 to 200 MWp/a

nominal capacity may be necessary for pre-qualifications for large scale manufacturing. Participation and collaboration of competing equipment and module manufacturing companies will be an effective way to generate synergies in most cases. A proper handling of IP is important.

Expected deliverables	**Timeline** (targets)
Proof of concepts in a (quasi-continuous) mode near large-scale manufacturing with (equal or better) product quality: - materials already in use but modified; - alternative materials; - prototype-equipment for large scale manufacturing (modified existing); - alternative processing and equipment.	- 3 – 4 years (BOM minus 20%) - 4 – 6 years (BOM minus 40%) - 3 – 4 years (capex minus 20%) - 4 – 6 years (capex minus 40%)

Party / Parties (countries / stakeholders / EU)	**Implementation instruments**	**Indicative financing contribution**
Today EU equipment making companies are well established and still market leader worldwide in most technologies. Most of these companies are placed in Germany, Switzerland, Italy and the Netherlands. A European module manufacturing industry with high market participation is small presently. For effective R&I, a larger scale manufacturing industry is important. Political decisions and regulations can play an important role. Accepted international collaborations might be important if added value can be shown on a high level for Europe. Parties ready and already active are e.g. in product manufacturing SolarWorld, Photowatt, Avancis, Solibro, Manz etc., in equipment manufacturing Meyer Burger (CH/DE), centrotherm (DE), Manz (DE), Singulus (DE), von Ardenne (DE), Tempress (NL), VDL (NL), AMAT (EU/USA), etc. and have to be supported by the existing world class institutions FhG-ISE, CEA-INES, EPFL-CSEM, imec, ISFH, ECN, ZSW and others). Additionally, upstream parts of the silicon value chain are provided by up to 6 research and 14 industry partners including machine manufacturing, producers of Si materials, Si ingots and wafers in Norway. Proposed FLAGSHIP “Production equipment for high-tech large-scale productions for PV (with subgroups of cSi, thin films and combinations thereof), maybe together with spin-offs of display,	Many of the topics are with stakeholders from several member and associated states; therefore EU funding should be applied; if topics are dominated by stakeholders from one member state EU and national funding should be combined. For establishment of a Flagship project on “High-tech large-scale production equipment” EU lead funding is recommended. As a result worldwide competitiveness and leadership can be kept and secured.	As content and stakeholders are dominated by equipment and manufacturing industry all projects are based on private-public-partnership with shares of public funding from 50% to 25% depending on TRL levels i.e. maturity for commercial exploitation.

electronics and storage technologies". Proposed FLAGSHIP: "Pilot lines" (cSi: wafer-cell-module, thin film: integrated) with relevant capacity of 300 MWp/a)		
Running activities		
Member States and regions: support for industrial organizations, joint projects between industry and research institutes and support for R&D infrastructure like		
• Germany The set-up of R&D infrastructure is supported. The infrastructure is situated at research institutes so that it can be used by the industry for a quick and easy testing and implementation of new processes into the manufacturing process as well as for the development of industry relevant processes. E.g. projects "CUT A" (Fraunhofer ISE) or "ProSolar" (ISFH) for advanced cSi modules or "VariFast CIGS" (ZSW) for CIGS technology.	National funding	~ 14.2 million euros funding
Project "FlexFab" (RCT Solutions, ISC Konstanz): Development of flexible manufacturing equipment for advanced cSi technology with system control via "Industry 4.0" / "smart factory"	National funding and industry resources	~ 3.0 million euros total with ~ 2.0 million euros funding
Project "Cheops" (Singulus, Fraunhofer ISE, camLine, MIB Messtechnik): Development of wet chemical multi-usage equipment including methods for self-testing to reduce equipment failures	National funding and industry resources	~ 3.8 million euros total with ~ 3.0 million euros funding
• Turkey National support for new generation solar cell systems by means of "1511 - Research & Technology Development and Innovation Program"	National funding and industry resources Support will be given to production new generation solar cells via two different calls	tbd
• Italy Project "PIPELINE" - Prototype process line for Si heterojunction solar cells": Low environmental impact and high efficiency production process: (ENEA, RISE Tech, Elettrorava spa)	National Funding and industry resources	~ 1.7 million euros (2017-2019)

R&I Activity n. 6 - Cross-sectoral research at lower TRL

Cross-sectoral research at lower TRL	
Targets: Closer collaboration between national PV labs for the sake of shared costs in development of new technologies and supporting European industries to facilitate a shorter time-to-market (T2M).	**Monitoring mechanism**: number of collaborations of national labs and resulting co-operations with industry - monitored by national funding agencies
General Description: With respect to high quality R&D, national research labs in Europe are still the leading institutions worldwide. A closer cooperation of these labs could help maintaining this position in order to support European industry with cutting edge research results. The focus will lie on cost sharing in research and technology development and significant lower time-to-market (T2M) times. On a topical level activity 6 covers innovation in all the other activities of this Implementation Plan, namely PV for BIPV and similar applications, technologies for silicon solar cells and modules with higher quality, new technologies & materials, operation and diagnosis of photovoltaic plants and manufacturing technologies, but will focus more on the innovation system as such. The activity will build on existing research capacities. The implementation of joint activities between the labs may be taken up jointly by MS's but may also take place in the existing European Innovation system and EERA. Explicitly this activity should use but not duplicate any work done previously in the SET plan by the JRC, ETIP or Eranet / Cofund.	
TRL: The TRL level may depend on the research topic but will lie between TRL 3 and 6.	
Total budget required: As a first approach, no additional budget is needed as resources for national labs are already available and "only" have to be re-allocated for cooperation projects. However, additional budget will be needed if the demand for exchange becomes higher than provided. Furthermore, alignment of research implies the long term allocation of resources for R&D into the proposed program lines in order to avoid "stop and go" cycles of decisions based on a project level and individual calls.	
Expected deliverables	**Timeline**
inventory of ongoing collaborations and additional opportunities	2018
joint R&D projects between national labs with relevance for the strategic targets outlined in the PV Implementation Plan	from 2018 on
co-operation between industry and labs based on the findings of the inter-lab co-operation	from 2020 on

Party / Parties *(countries / stakeholders / EU)	**Implementation instruments**	**Indicative financing contribution**
ongoing activities		
joint research on Thin-film solar cells within the Solliance initiative between Belgian, Dutch and German research centres (http://solliance.eu/)	joint research	
transnational cooperation between leading European research-driven clusters within the EU project SOLARROK (http://www.solarrok.eu/)	joint research	approx. 2.2 mil. € from FP7-REGIONS
planned activities		
programs for an increased exchange of staff		approx. 25.000 € per person and year for travel and material expenses[23]
additional activities on joint usage of infrastructure like - PV test sites - …		
initiate a (virtual) high performance computer centre for R&I on PV and maybe renewable energies in general[24]		eventually, new instruments on funding research infrastructure have to be developed on an European level

[23] personal costs are expected to be beard by the home institution
[24] see for example the High Performance Computing (HPC) center at the National Renewable Energy Laboratory, www.hpc.nrel.gov

Annex II – Members of the TWG

Member States (11)

member		alternate
Belgium - Walloon region	Laurence Polain	
Belgium - Flemish region	Lut Bollen	
Cyprus - University of Cyprus	George E. Georghiou	Aris Bonanos
Estonia - Ministry of Economic Affairs and Communications	Siim Meeliste	
France - Ministère de l'Environnement, de l'Energie et de la Mer	Louise Oriol	
Germany – Project Management Jülich (PtJ) **(Chair)**	Christoph Huennekes	Johannes Lambert
Italy - National Research Council of Italy	Massimo Mazzer	
Netherlands - Netherlands Enterprise Agency	Otto Bernsen	
Norway - The Research Council of Norway (RCN)	Trond Inge Westgaad	Tor Ivar Eikaas, RCN, Astrid Stavseng, Ministry of Petroleum and Energy
Spain - Centre for the Development of Industrial Technology (CDTI)	Pilar Gonzalez Gotor	M. Luisa Revilla
Turkey - TUBITAK	İlknur Yilmaz	Cagri Yildirim

European Commission (4)

member		
DG RTD	Fabio Belloni	
DG RTD	Maria Getsiou	
DG ENER	Pietro Menna	
EC JRC	Arnulf Jäger-Waldau	

ETIP & Industry (15)

member		alternate
EUREC / ETIP PV Secretariat	Greg Arrowsmith	
Enel Green Power	Fabrizio Bizzarri	
Manz AG	Bernhard Dimmler	
DSM	Oscar Goddijn	Ellen Oerlemans
SETA Network	Silke Krawietz	
Becquerel Institute	Gaëtan Masson	
SolarWorld AG	Milan Nitschke	
Consultores de Energía Fotovoltica SL	Emiliano Perezagua	
EERA PV (Fraunhofer ISE)	Simon Philipps	Ivan Gordon

member		**alternate**
IMEC	Jef Poortmans	
ECN - **(Co-Chair)**	Wim Sinke	
University of Ljubljana	Marko Topič	
First Solar	Andreas Wade	
Singulus	Peter Wohlfart	
3E	Achim Woyte	