Strategic Energy Technology Plan

IWG Solar PV

IMPLEMENTATION WORKING GROUP (IWG) ON PHOTOVOLTAICS (PV) IMPLEMENTATION PLAN

2023 revision

final draft

July 2023

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1. INTRODUCTION

1.1. THE INTEGRATED SET PLAN

The European energy policies are currently faced with two mayor challenges: On the one side, there is the world energy crisis with unreliable supply of conventional energy resources resulting in high energy prices for all consumers. On this background, the EU supports a global, clean and just energy transition to ensure sustainable, secure and affordable energy. On the other side and in addition to the first challenge, stable long-term strategies are crucial to help achieve the transition to a real sustainable European energy system. Here, broader and long-term development targets form the basis of the goal set by the Paris Agreement – holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C.

One key element of all European energy policies is to accelerate the usage of green energies. The European Green Deal focuses among others on Renewables, which are the cheapest and cleanest energy available, and can be at least partially produced domestically, thereby reducing the need for energy imports. Therefore, the EU will speed up the green transition and spur massive investment in renewable energy.

The main measure to support the European green transition on a technological level is the Strategic Energy Technology Plan (SET Plan) as part of the Energy Union. The SET Plan was launched in 2007 as a key step in creating an energy technology policy for the EU. It provides a shared vision and overarching goals while providing a basis for coordinating national and European activities to accelerate the development and deployment of efficient and cost-effective low-carbon energy technologies. The SET-Plan plays a central role in the implementation of the research, innovation and competitiveness dimension of the Energy Union. The SET-Plan was last updated in 2015. Efforts are already taken to align the SET Plan with the European Green Deal and REPowerEU targets.

The integrated SET Plan identifies the strategic priorities and actions needed to accelerate the EU energy system transition in a cost-effective way. Obviously, within the SET Plan, renewable energy technologies are at the heart of the new energy system with photovoltaic solar energy (PV) as one of the main pillars. 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.

1.2. PHOTOVOLTAIC SOLAR ENERGY (PV) TECHNOLOGY

Electricity produced from renewable energy sources is expected to become a cornerstone of the future sustainable, climate-neutral energy system. It may become the ‘primary fuel of the future’, not only serving the well-known electricity needs, but also powering heating and cooling in urban environments and industry, transport and mobility, and in some parts of the world, desalination. Moreover, it enables production of renewable fuels and feedstocks (such as hydrogen or hydrocarbons, when combined with carbon from sustainable sources). Thus, renewable energy and other low-carbon technologies, with PV solar energy as a prominent element, are drivers of the energy transition and will play a key role in achieving the targets[1].

Additionally, the related industry sectors have been identified as value chains of key strategic and economic importance. In this context, rapid large-scale deployment as well as sustainable manufacturing of PV solar energy in Europe are essential to reduce dependence on imported fossil fuels and critical advanced technologies. This is underlined by the establishment of the European Solar PV Industry Alliance (ESIA)[2] under the Green Deal Industrial Plan. The PV sector offers great opportunities for job creation and can thus make important contributions to the economy and to the EU recovery plan NextGenerationEU.

Availability of world-class technologies, solutions, policies and instruments is a prerequisite for success and joining forces on research and innovation between Member States is a proven approach to benefit in an optimum way from Europe’s distributed strengths in energy science and technology. To facilitate cross-border collaboration on these fields, the Clean Energy Transition Partnership (CETP)[3] has been established and a corresponding Strategic Research and Innovation Agenda (SRIA)[4] has recently been developed. In addition to the CETP SRIA for the entire ‘clean energy’ field, the European Technology and Innovation Platform for Photovoltaics (ETIP PV)[5] has developed a dedicated SRIA[6] for PV solar energy which describes the PV research and innovation challenges in detail.

Over a period of just a few decades, PV solar energy has developed from an option serving high-value niches to a renewable energy technology prepared for competitive multi-terawatt-scale deployment. The achievements obtained in thirty years since the early days of market development by research, innovation, industry development and deployment with important contributions from European companies, organisations and countries are impressive:

- Increase of the annual and cumulative global installations by well over two orders of magnitude, reaching 175 gigawatt-peak (GWp) and 940 GWp in 2021, respectively[7] (the 1 terawatt-peak (TWp) boundary has been passed in March 2022[8]), achieved by successful market incentives and

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[1] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

[2] https://solaralliance.eu

[3] https://ec.europa.eu/info/sites/default/files/research_and_innovation/funding/documents/ec_rtd_he-partnerships-clean-energy-transition.pdf

[4] CETP SRIA vs1.0

[5] http://www.etip-pv.eu/

[6] ETIP PV SRIA

[7] IEA PVPS Snapshot of Global PV Markets 2022

[8] https://www.pv-magazine.com/2022/03/15/humans-have-installed-1-terawatt-of-solar-capacity/

development of commercial markets. Approximately 20% of the cumulative capacity is installed in Europe;

- Reduction of typical component and system cost (and prices) as well as generation cost (Levelized Cost of Energy; LCoE) by more than an order of magnitude, resulting from a powerful combination of innovation and economies of scale in manufacturing and installation, with LCoE values now indicatively ranging from less than 0.02 to 0.10 €/kWh for different geographical locations, system sizes and types and financing conditions[9,10];

- Performance enhancement of commercial solar panels by more than half, with 22% efficient solar modules now available at low cost and a range of silicon and thin-film module technology options on the market to serve different applications;

- Track record of long lifetime and high reliability, with PV systems in operation for 25 years or even more;

- A well-filled pipeline of new technologies and advanced version of existing technologies (silicon, thin film, tandem, and more) in laboratories and pilot production, enabling robust continued performance increase over time, even well beyond the limits of current technologies, opening up new applications and facilitating further cost reduction as well as reduction of materials and processing energy consumption;

- A range of new PV system types, designs and applications demonstrated for small- and medium-scale decentralized as well as large-scale central use, aimed at physical integration[11] (e.g. in buildings, infrastructure and vehicles), combined/ dual purpose use (e.g. PV with agriculture; agrivoltaics[12]) and energy system integration (advanced power management, battery storage and hydrogen production). The range of new options includes floating systems (currently for inland waters, but potentially also offshore)[13];

- Strongly reduced embedded energy and carbon footprint, with the system energy payback time now close to 1 year for applications in Europe[14]. Together with the typically very short lead times for project development, this makes PV solar energy a key technology for rapid and large-scale reduction of greenhouse gas emissions.

1.3. SET PLAN STRATEGIC TARGETS ON PV

This Implementation Plan describes the technological and socio-economic research and innovation (R&I) activities that need to be implemented in order to achieve the strategic targets of the Integrated SET-Plan. Besides reflecting the general goals for PV already described in the first Implementation Plan, additional topics come into view. Amongst others, the new IP addresses socio economic aspects in more detail than before. Moreover, by deepening the activities on integrated PV, the basis for collaborations with other IWGs, namely Energy Efficiency in Buildings and Concentrating Solar Power (CSP), is described in a more concrete way.

In total, on the background of the 2022 REPowerEU Plan the importance of the updated IP becomes obvious: The EU Solar Energy Strategy[15] foresees a boost of the roll-out of photovoltaic energy. As part of the REPowerEU plan, this strategy aims to bring online over 320 GW of solar photovoltaic newly installed by 2025, over twice today's level, and almost 600 GW by 2030[16].

Whereas the 2017 Implementation Plan[17] was organised along a structure developed specifically for this purpose, this updated and renewed 2023 Implementation Plan adopts the Challenges and

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[9] Levelized Cost of Electricity- Renewable Energy Technologies (Fraunhofer ISE, 2021)

[10] IEA PVPS Trends in Photovoltaic Applications 2021

[11] See various reports at https://etip-pv.eu/publications/etip-pv-publications/

[12] Agrivoltaics

[13] Floating solar and Offshore solar

[14] Photovoltaics Report (Fraunhofer ISE, edition February 2022)

[15] https://energy.ec.europa.eu/topics/renewable-energy/solar-energy_en#eu-solar-energy-strategy

[16] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

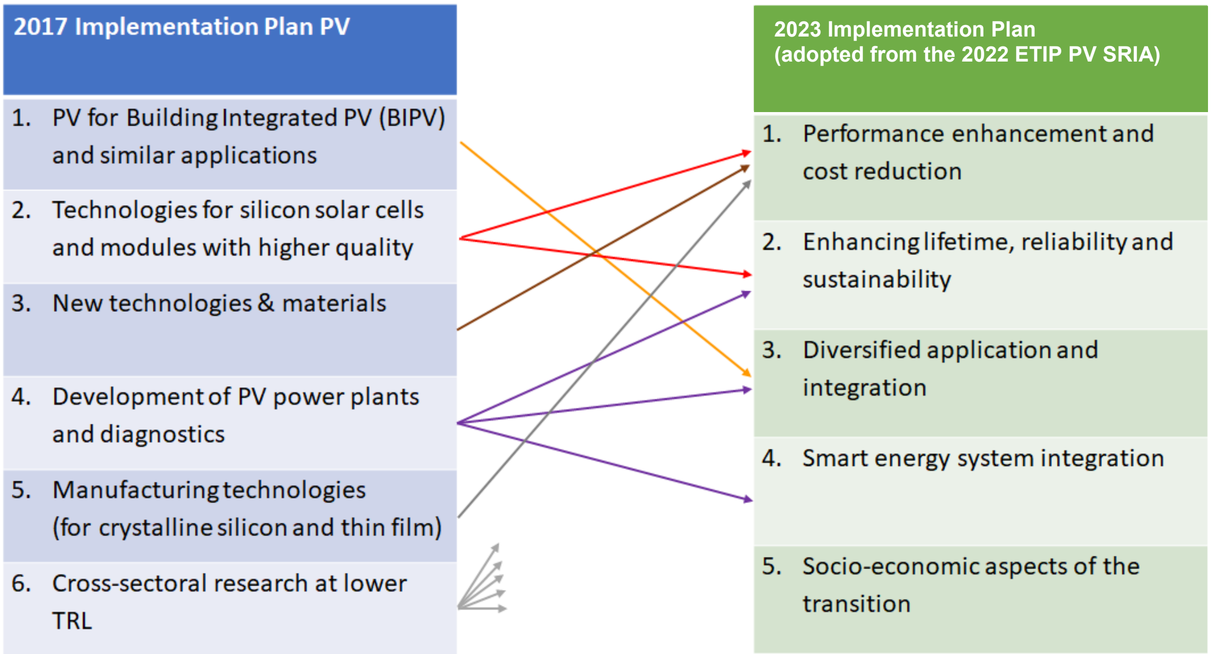
[17] 2017 SET-Plan Implementation Plan PV, see also https://www.iwg-pv.eu/implementation-plan

corresponding targets and R&I topics from the 2022 ETIP PV SRIA[18]. This will contribute to a common understanding of PV R&I priorities at European and Member State levels and facilitate the alignment of R&I and cross-border collaboration aimed for.

The schematic below shows the relation (mapping) between the structure and topics in the 2017 and 2023 Implementation Plans. Apart from the obvious differences in structure, the following changes are important to note:

- Cross-sectoral research at lower TRL (2017 IP) has been fully integrated into the 5 Challenges of the 2023 IP;

- Socio-economic aspects of the transition were largely beyond the scope of the 2017 IP, but feature as one of the 5 Challenges in the 2023 IP, emphasizing their importance for successful rapid, large-scale deployment of PV.



In the end, the mapping underlines that the 2017 activities will completely transferred into the new 2023 scheme.

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1.4. IMPLEMENTATION WORKING GROUP

According to the common principles of the SET Plan, in 2017 an initial Implementation Plan for PV was elaborated, endorsed and published. With the aim of a sustained execution of this plan, an Implementation Working Group (IWG) was set up. It is composed of 22 members forming a balanced group of SET Plan countries, Stakeholders and EC (see Annex II for further details).

- SET Plan countries are committed to use their energy R&I national programmes and policies to implement some of the R&I activities; and are preferably interested in developing and pursuing joint research with other countries. Country representatives in the IWG PV are government representatives, or nominated by their governments.

- Stakeholders are experts from ETIP[19] PV, EERA[20] and industry not organized in the ETIP.

- The EC facilitates and supports the IWG as needed in agreement with the Chair and Co- Chair.

The nomination of the Chair and Co-chair took place 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 C. Sinke, Co-chair of the European Technology and Innovation Platform Photovoltaics, Principle Scientist, Solar Energy at TNO Energy Transition, The Netherlands, and Professor for Photovoltaic Energy Conversion, University of Amsterdam

- Supported by EC: Maria Getsiou, Directorate-General for Research & Innovation, Directorate G – Energy, Unit G.3, Brussels

Since 2017, the IWG conducted a series of activities.

1.4.1. MONITORING OF NATIONAL RESEARCH, DEVELOPMENT AND INNOVATION (RD&I) ACTIVITIES

One main topic of the work of the IWG PV was the monitoring of national RD&I activities. The aim was to examine the focal points of activities within the IWG Member States and Regions and to describe the scope of these initiatives. Thereby, the 6 topics defined in the IP were used for catego-rization. As a first outcome, an internal report was drafted in December 2018. An updated version became available in March 2019.

From mid-2019 on, the monitoring of national RD&I activities was transferred to the Coordination and Support Activity (CSA) “PV Impact”. One aim of “PV Impact” was the installation of a European PV Project Database and the analysis of the information gained. From early 2020 on, “PV Impact” was in regular exchange with the chairs of IWG and a mutual support was provided concerning the collection and assessment of data. One outcome for example is the “PV Impact” report “Journal articles on R&D spending” and there are more analyses to come[21].

It turned out that there is a significant support for RD&I on PV throughout Europe. At the same time, the motivation, intensity and focal points of interest differ from country to country.

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[19] European Technology & Innovation Platform

[20] European Energy Research Alliance

[21] see https://pvimpact.eu/news-resources/reports/

1.4.2. COOPERATION AND LINKAGE WITH ETIP PV

Another important task of the IWG was the monitoring of technical and market related progress of PV in the EU. Since the beginning of the TWG / IWG activity, a close cooperation with the ETIP PV (European Technology and Innovation Platform for Photovoltaics) was established, which turned out to be essential for this monitoring activity. At two meetings, one in Brussels in October 2019, and one online in May 2020, Key Performance Indicators (KPI) for PV and consequences for the IP were discussed. This led to an initiative for a revision of the IP that started in 2021. IWG PV expects to complete this review by mid-2023. The new IP will be based on the Strategic Research and Innovation Agenda (SRIA) of ETIP PV and will offer an added value by taking the activities of the IWG Member States and Regions into account. Here again, the monitoring of national RD&I activities (see above) conducted by “PV Impact” plays an important role.

1.4.3. SUPPORT OF SET PLAN ACTIVITIES

IWG PV was able to support the SET Plan activities over the last years in different ways. Initially, the IP was presented and discussed at the 2017 SET Plan conference in Bratislava. An update on the work of the IWG was given at the SET Plan Steering Group Meeting in September 2019. For the SET Plan conference 2020 IWG provided input on the project pipeline for recovery funds. The IWG was as well present at the EU Sustainable Energy Week 2020.

In addition, representatives of the IWG participated in different match-making events of SOLAR-ERA.NET (May 2019) and “PV Impact” (September 2019).

Finally, in April 2022 IWG PV in cooperation with ETIP PV made a statement on regulatory sandboxes reflecting environmental aspects for PV installations.

2. PRIORITY TECHNOLOGY ACTIONS (R&I ACTIVITIES)

2.1. THE PROCESS TO DEFINE THE UPDATED PRIORITY TECHNOLOGY ACTIONS (R&I ACTIVITIES)

Research and innovation needed to achieve the ambitious European targets concerning solar energy deployment as well as technology and industry development is described in detail in the Strategic Research & Innovation Agenda (SRIA) of the European Technology and Innovation Platform for Photovoltaics (ETIP PV), which has been published in May 2022. The SRIA covers R&I to be performed on European and Member State levels as well as by public and private sectors. Because the SRIA is comprehensive and has been developed in close consultation with many stakeholders throughout Europe, it forms an excellent basis for this Implementation Plan as well. Therefore we have adopted the SRIA and thus achieve optimum consistency in priorities, messages and structure of the Implementation Plan.

The core of this Implementation Plan is a description of R&I activities as adopted from the ETIP PV SRIA, to be carried out by SET Plan countries and stakeholders and, within its mandate, the EC in order to achieve the targets set in the DoI. The final selection of (priority) activities is made taking the country-specific priorities as well as added value of cross-border collaboration into account.

2.2. THE R&I ACTIVITIES

As outlined in the foregoing, this Implementation Plan has adopted the structure of the ETIP PV SRIA. It is noted that the SRIA describes 'Challenges' with related Objectives, which are then addressed through research and innovation (i.e. R&I Activities) in Roadmaps. To avoid any confusion that may arise, in the following we adopt the SRIA terminology.

Details of the R&I Activities can be found in the ETIP PV SRIA, specific targets and contributions by Member States participating in the Implementation Working Group PV are described in Annex I.

2.3. OVERARCHING CHALLENGES

Making the energy transition a European success with PV as a key building block

A. Enable rapid and very large scale deployment in a sustainable manner

- Further reducing the levelized cost of electricity in a sustainable manner to keep/make PV competitive in all parts of Europe while allowing for (the additional cost of) energy system integration and integration in the living environment;
- Making PV available for a wider range of applications, with emphasis on flexible integration (buildings, infra, etc.) and dual functionality (agro-PV, etc.), as well as floating systems;
- Making PV components and systems circular.

B. (Re-)build the strategic value chain for PV by exploiting Europe's technological leadership

- Manufacturing of high-performance, circular products;
- Large-scale deployment in a wide range of applications;
- Energy system integration.

2.4. CHALLENGES

2.4.1. PERFORMANCE ENHANCEMENT AND COST REDUCTION THROUGH ADVANCED PV TECHNOLOGIES AND MANUFACTURING

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OBJECTIVE 1: PV MODULES WITH HIGHER EFFICIENCIES AND LOWER COSTS

This objective focuses on **improving efficiency and reducing costs of PV modules**. It covers the **various PV technologies** that have already reached industrial maturity level as well as emerging technologies.

- **Roadmap 1 | Silicon PV modules**
  There is potential for further innovation in performance, integration and sustainability enabling large-scale deployment.

- **Roadmap 2 | Perovskite PV modules**
  The long-term vision is that they will be produced at very low costs, be highly efficient and stable and represent a broad scope of embodiments: flexible, rigid, opaque, semi-transparent...

- **Roadmap 3 | Thin-film (non-perovskite) PV modules**
  Module efficiencies should be comparable to current PV technologies within 5 years. Manufacturing should quickly achieve comparable costs compared to currently commercial technologies.

- **Roadmap 4 | Tandem PV modules**
  For 2030, these should reach a market share of more than 5% and should successfully transition to mass market applications, while demonstrating long-term performance comparable to the single-junction technologies, clear advantages in terms of LCOE and in the environmental footprint.

OBJECTIVE 2: SYSTEM DESIGN FOR LOWER LCOE OF VARIOUS APPLICATIONS

This objective focuses on R&D needs **beyond the PV module**, and on improving the energy yield of systems.

For the past decades, the focus of cost reduction & efficiency improvements has mostly been on PV modules, as they have traditionally been the costliest component of a PV system. With the strong reduction of their prices, other parts of the value chain become more important for lower LCOE. This may include as well the combination of PV and CSP systems.

- **Roadmap 5 | Balance of System (BoS) and energy yield improvement**
  Focusing R&D on other components and activities, such as installation, operation, maintenance, decommissioning, etc.

OBJECTIVE 3: DIGITALISATION OF PV

The digital transition presents key opportunities for the PV sector: not only can new digital technologies allow for the emergence of new solar business models and for the improvement of existing models, they can also be used to reduce costs and increase performance at almost every point of the value chain.

- **Roadmap 6 | Digitalization of PV manufacturing**
  Introducing digital technologies to reduce cost and increase the quality of PV value chain manufacturing.

- **Roadmap 7 | Digitalization of PV systems**
  Introducing digital technologies to increase energy yield, and to make PV technology suited for all emerging new applications and a dependable component of the energy system of the future.

2.4.2. LIFETIME, RELIABILITY AND SUSTAINABILITY ENHANCEMENTS (THROUGH ADVANCED PV TECHNOLOGIES, MANUFACTURING AND APPLICATIONS)

OBJECTIVE 1: SUSTAINABLE AND CIRCULAR SOLAR PV

This objective focuses on reducing PV's impact on our environment, across the entire value chain (production, transport, installation and operation of PV systems).

- **Roadmap 1 | Refuse and Rethink, Reduce (Low environmental impact materials, prod-ucts, and processes**
  Improving PV technology over the entire value chain, with regards to consumption of materials, energy demand and carbon emissions.

- **Roadmap 2 | Reuse, Repair and Refurbish (Designs, systems and O&M for reuse)**
  Diverting PV "waste" from the recycling path.

- **Roadmap 3 | Recycle and recover**

- **Roadmap 4 | Technologies for sustainable manufacturing**
  Investigating ways of reducing both the energy and GHGs in PV production.

- **Roadmap 5 | Eco-labelling and energy-labelling**
  Focusing on accurate, and up-to-date, life cycle inventory databases, including the Eco-Invent Database, GABI database and the European Commission Life Cycle data information system.

OBJECTIVE 2: RELIABLE AND BANKABLE SOLAR PV

The most effective strategy for reliable and bankable solar PV is to **prevent the occurrence of failures** and by reducing the impact of failures once they become evident.

A **yield assessment** with reduced uncertainties can lead to a much more favourable business model. **Procurement** is the next important step where extended testing beyond what is prescribed by the standards can increase the confidence of the right choice of PV components.

- **Roadmap 6 | Quality assurance to increase lifetime and reliability**

- **Roadmap 7 | Increased field performance and reliability**
  Novel technologies make the increased reliability and field performance a continuous industry demand. Solutions available on the market will need to be updated to capture innovation trends.

- **Roadmap 8 | Bankability, warranty and contractual terms**

2.4.3. NEW APPLICATIONS THROUGH INTEGRATION OF PHOTOVOLTAICS (FOR DIVERSIFIED AND DUAL-PURPOSE DEPLOYMENT AND ENHANCED VALUE)

OBJECTIVE 1: PHYSICAL INTEGRATION OF PV INTO THE BUILT ENVIRONMENT, VEHICLES, LANDSCAPES & INFRASTRUCTURES

The inherent **modularity of the PV** enables it to be **integrated seamlessly into many different objects**, allowing space to be used efficiently.

PV-enabled products must meet the requirements of the original product, with EU-harmonised rules to create markets large enough to address cost-efficiently. As most of 'IPV' value chains are in Europe, **the integration of PV creates huge opportunities for European value and job creation**.

- **Roadmap 1 | PV in buildings**
  Nearly zero energy buildings are promoted as a decarbonisation solution by regulators, and require the integration of renewable energy systems.

- **Roadmap 2 | Vehicle Integrated PV**
  VIPV enables the electrification of transport system by converting solar energy directly on the vehicle.

- **Roadmap 3 | Agrivoltaics and landscape integration**
  Agrivoltaics allow for the simultaneous use of land for both agricultural and photovoltaic use, while supporting the decarbonisation of the sector.

- **Roadmap 4 | Floating PV**
  The main market driver for floating solar is the search for area in locations with a high population density.

- **Roadmap 5 | Infrastructure Integrated PV**
  The integration into infrastructural objects such as road pavement, noise barriers, crash barriers, dikes, landfills, flyovers and road roofing.

- **Roadmap 6 | "Low-power" energy harvesting PV**
  Photovoltaic Energy harvested in low light conditions or artificial light can be used to energize sensors, internet-of-things devices and other electronics.

2.4.4. SMART ENERGY SYSTEM INTEGRATION OF PHOTOVOLTAICS (FOR LARGE-SCALE DEPLOYMENT AND HIGH PENETRATION)

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OBJECTIVE 1: ENERGY SYSTEM INTEGRATION

PV is growing strong in independent applications at all levels: on roofs or facades of buildings for both domestic and commercial use, as well as for commercial systems of various sizes. In the years to come, **PV should be looked at as active contributor of the integrated grid** utilising dependable forecasting tools for improving the reliability of the complete system.

- **Roadmap 1 | More intelligence in distributed control**
  This roadmap aims to add intelligence to the PV systems to be responsive to system needs.

- **Roadmap 2 | Improved efficiencies by integration of PV-systems in DC-networks**
  The objectives of this roadmap include developing systems and solutions for which PV as the energy source is directly connected to DC driven systems to achieve improved efficiencies.

- **Roadmap 3 | Hybrid systems including demand flexibility (PV + Wind + Hydro with embedded storage + batteries + green hydrogen/fuel cells or gas turbines, etc.)**
  The objective of this roadmap is to develop systems and solutions for which PV, as an integral contributor of interconnected systems, can offer hybrid solutions that better meet needs of the integrated grid.

- **Roadmap 4 | Aggregated energy and virtual power plants (VPPs)**
  The objective of this roadmap is to develop systems and solutions for which PV as an integral contributor of distributed generation can be pivotal in building functional energy communities aggregated and operated through advance distributed controls in hierarchical set up with the integrated grid.

- **Roadmap 5 | Interoperability in communication and operation of RES smart grids**
  Future inverter systems need to be interoperable from the automation/control and communication point of view and they should provide advanced services including auto-configuration of PV plant components. Current issues include the lack in the harmonization of PV plant control and the use of proprietary solutions for monitoring.

2.4.5. SOCIO-ECONOMIC ASPECTS OF THE TRANSITION TO HIGH PV CONTRIBUTION


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OBJECTIVE 1: HIGHER AWARENESS OF SOLAR PV-RELATED EXTERNALITIES AND BENEFITS

- **Roadmap 1 | Wide societal involvement and participation for solar PV deployment**
  PV is a renewable energy which can be employed by everyone. Facing the need to increase renewable electricity generation to meet the goals of the Green Deal and the Paris Agreement, it is a logical step to involve people/society to utilise PV technology on a wider scale.

- **Roadmap 2 | Developing a PV hotbed for urban implementation**
  PV is the only renewable energy technology that can enable renewable electricity generation in urban and highly-dense spaces throughout Europe. Cities and urban regions will be one of the major boosters to increase the implementation of PV within the current decade.

OBJECTIVE 2: ECONOMIC & SUSTAINABILITY BENEFITS

- **Roadmap 1 | Manufacturing phase**
  If the shares of PV components manufactured increases as a result of a revival of the European solar industry, more than 100 000 jobs in the up-stream sector could also be created. The upstream sector encompasses both low educational jobs and high educational jobs.

- **Roadmap 2 | Installation phase**
  The roll out of PV installations create jobs. These jobs created in the installation phase are spread between low educational jobs, medium educational jobs and high educational jobs.

- **Roadmap 3 | Operation phase**
  In addition, the number of people needed for operation and maintenance will increase as the cumulative PV capacity grows and the age of the running PV systems increases.

3. SUMMARY AND NEXT STEPS

The Implementation Working Group on PV, composed by representatives of interested SET Plan countries and relevant stakeholders, representing industry and academia, has identified the need to revise the 2017 SET Plan Implementation Plan for Photovoltaics and thus updated 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 2021 / 2022.

The priority R&I activities are considered to be essential for achieving the corresponding SET Plan targets. There is a significant need for further development of the actions. In addition, further investments, funding sources and financial instruments[22] will be needed to fully achieve the 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. In order to keep the momentum and ensure the delivery of the work so far planned, meetings will be organised as necessary.

IWG PV would support all measures to strengthen the role of the SET Plan and its IPs concerning a more strategic orientation of the EU and national RD&I policies in the energy sector, especially on the background of climate change mitigation targets and the current energy supply crisis.

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22 At EU level, instruments such as InnovFin Energy Demonstration Projects and the future Innovation Fund are obvious potential sources of finance.

4. ANNEX I – R&I ACTIVITIES

The Key Performance Indicators (KPIs) and targets were evaluated and discussed between IWG, CSA PV Impact and ETIP PV in multiple iterations. The following results are from the final ETIP PV SRIA of Q2 2022.[23] It is noted, however, that recent geopolitical developments and related effects on supply chains, materials and prices may have an impact on some targets.

In addition, an estimation for the **resources** needed was taken form PV Impact (see also table “statistical data of budget” in annex III). Based on this survey, the overall PV R&D budget in Europe varied somewhere between 660 Mio. € (CSA PV Impact data collection) to 1.600 Mio. € (IEA ref) for the period 2016 to 2020 with big differences in the total amount spend by single Member States. Although these numbers show a broad range, an annual R&D spending of at least 200 Mio. € seems necessary to only continue the current activities.

Questioners to the Member States inside the IWG showed that the priority of topics differs between Member States. One possible reason seems to be the regional PV research and industry land-scapes. Since the IP targets for 2030 are significantly more ambitious than before, it underlines the necessity to increase the support for the PV sector even more.

[23] https://media.etip-pv.eu/filer_public/ea/68/ea68ecf6-f265-4979-84ba-dc004e6cd9a5/sria_summary_web.pdf

4.1. R&I ACTIVITY N. 1 - PERFORMANCE ENHANCEMENT AND COST REDUCTION THROUGH ADVANCED PV TECHNOLOGIES AND MANUFACTURING

Topic: Performance Enhancement and Cost Reduction through Advanced PV Technologies and Manufacturing		
Objectives 1. PV modules with higher efficiencies and lower costs 2. System design for lower LCoE of various applications 3. Digitalisation of Photovoltaics		
	KPI	Target 2030
Silicon PV Modules	silicon-based cell and module manufacturing capacity with low carbon footprint in Europe	100 GWp
	LCoE in Europe	0.025 €/kWh for utility-scale PV <0.05 €/kWh for integrated Photovoltaic elements
	Module conversion efficiency	25%
	Module lifetime	50 years
	Energy ROI	50 in Southern Europe
Perovskite PV modules	LCoE of Pk-PV technology	Equal to or lower than that for c-Si
	The yield-specific CO2 footprint of Pk- PV technologies	<80% of c-Si production and modules should be fully recyclable.
	Commercially available, Pk-based module efficiency	>23%
thin-film (non-perovskite) PV modules	LCoE of thin-film technology	Equal to or lower than that for c-Si
	Indium or tellurium reduction	Factor 3 per W
	global market share for thin-film-based modules	10%
Tandem-PV modules	Efficiency	at least 5% absolute above respective single junction technology
	Lifetime	at par with respective single junction technology
	Production cost of additional junction	less than 8 €/m2
Balance of System and energy yield	BOS components operational lifetime of complete PV systems	50 years

improvement	LCOE BOS components to contribute to the general objective of making PV the most competitive energy source)	0.025 EUR/kWh and 0.05 EUR/kWh for IPV
Digitalisation of PV manufacturing	The long-term vision is to evaluate and link the data from component production to the construction and operation of PV power plants. Realize a self-learning and self-optimizing factory using AI-based data analysis.	
Digitalisation of PV systems	Novel digital PV-systems will be developed combing PV technology with photonics, micro- and power-electronics, sensors technology, energy storage, wireless communication, and computer science.	
Ongoing activities		
See **PV Impact database** at https://pvimpact.eu/towards-set-plan-targets-ip-progress/pv-projects-database/		
Outlook and planned activities		

Parties (countries / stakeholders / EU)	**Implementation instruments and Resources**
CET Partnership[24]	Call modules PV1 (Development of new efficient materials and modules for PV), PV2 (Decrease cost of high performance panels and increase lifetime) and MF1 (Manufacturing) of the Transition Initiative “Enhanced Zero Emission Power Technologies” (TRI 2)
Horizon Europe	CL5-2021-D3-02-04: Novel tandem, high efficiency Photovoltaic technologies targeting low cost production with earth abundant materials CL5-2021-D3-03-07: Stable high-performance Perovskite Photovoltaics CL5-2021-D3-03-13: Demonstration pilot lines for alternative and innovative PV technologies (Novel c-Si tandem, thin film tandem, bifacial, CPV, etc.) CL5-2022-D3-03-05: Novel Thin Film (TF) technologies targeting high efficiencies
National activities	
Belgium	
Cyprus	
France	The activities are promoted by ANR (1) and ADEME. In particular the PEPR TASE(2) and the PIA Investissements d'avenir (3) with the program France 2030 (4) and the announcement of President Macron about 100 GW of Solar PV capacity for France by 2050 (5) (1) https://anr.fr/fr/detail/call/programme-solaire-photovoltaique/ (2) https://www.cnrs.fr/fr/pepr/pepr-dacceleration-technologies-avancees-des-

[24] European Clean Energy Transition Partnership

	systemes-energetiques-tase (3) https://www.enseignementsup-recherche.gouv.fr/fr/investissements-avenir (4) https://www.gouvernement.fr/france-2030 (5) https://www.elysee.fr/front/pdf/elysee-module-19285-fr.pdf
Germany	7. Federal Program on Energy Research, call topics of the BMWK[25] on the development of production technologies and alternative PV materials and concepts
Italy	
Netherlands	The Durch Ministry of Economic Affairs and Climate funds RD&I projects through mission-oriented programs, in which specific topics for solar PV are articulated. For example in the mission program “Renewable electricity generation on land” (current target 42 TWh in 2030) there are solar specific targets for cost reductions and performance improvement.
Norway	The Research Council of Norway funds RD&I projects through several funding schemes and calls. The most important schemes for PV-research are the ENERGIX program that supports projects both in the R&D-sector and in industry within renewable energy, energy efficiency, energy system and energy policy and The Centres for Environment-friendly Energy Research (FME) that carry out long-term research targeted towards renewable energy, energy efficiency, CCS and social science aspects of energy research. For more information: Energy, transport and low emissions - portfolio (forskningsradet.no)
Spain	In Spain, the State Plan for Scientific and Technical Research and Innovation 2021-2023 - State Program to Promote Scientific-Technical Research and its Transfer offers support for PV on different levels. It is supplemented by the CDTI[26] – Mission Programme, a challenge-oriented approach programme to support large consortia projects, mainly with a focus on industrial research activities and the CDTI – R&I Projects.
Türkiye	As “Photovoltaic cells, panels and systems” are listed in the “TUBITAK 2022-2023 Priority RDI Themes”, project proposals which targeted above topic are prioritized during the evaluation stage of support programmes. The projects which serve to the objectives of priority RDI themes are supported via TUBITAK 1001 - Scientific and Technological Research Projects Support Program, TUBITAK 1501 - Industry RDI Projects Support Program, TUBITAK 1507 - Initial R&D Support Program for SMEs and TUBITAK 1602 - Patent Support Program. Moreover, the identified priority technologies and applications are also included and supported through the calls of the “Technology-Oriented Industry Move” within the scope of the National Technology Move by the Ministry of Industry and Technology.

[25] German Federal Ministry of Economic Affairs and Climate action
[26] Spanish Centre for the Development of Industrial Technology

4.2. R&I ACTIVITY N. 2 - LIFETIME, RELIABILITY AND SUSTAINABILITY ENHANCEMENTS

<table>
<tr><td colspan="3">Topic: Lifetime, Reliability and Sustainability Enhancements (through Advanced Photovoltaic Technologies, Manufacturing and Applications)</td></tr>
<tr><td colspan="3">Objectives
1. Sustainable and Circular solar PV
2. Reliable and Bankable Solar PV</td></tr>
<tr><td></td><td>KPI</td><td>Target 2030</td></tr>
<tr><td rowspan="3">Reduce</td><td>Energy required to produce MGS
Carbon footprint
Primary raw material usage for BOS i.e., concrete and steel</td><td>< 20 kWh/kg (current value 32 kWh/kg)
PV tandem system < 40 g CO2-eq/kWh, thin film single junction < 20 g CO2-eq/kWh
Reduction by at least 3% (4% reduction by 2030 and further 6-7% by 2050)</td></tr>
<tr><td>Primary raw material usage</td><td>Reduction of Plastic, glass, Al, and Cu, by at least 3% (respectively 3%, 4%, 4%,
2% reduction by 2030 and further 7%,
6%, 6%, 7% by 2050)</td></tr>
<tr><td>Acquisition of PV materials from European producers</td><td>Increase silicon metal by 20% (Norway, 6% global share in 2019), and silver by 30% (Poland, 20% global share in 2019)</td></tr>
<tr><td rowspan="4">Reuse</td><td>% repair/reuse after EoL of first life PV</td><td>>50%</td></tr>
<tr><td>years of operation for reused modules
cumulative lifetime minimum</td><td>>10 years
40 years</td></tr>
<tr><td colspan="2">Milestone</td></tr>
<tr><td colspan="2">Demonstrate increasing amount of repair/reuse up to 50-60% and implementation of clear triage protocols in the EoL sector for first life PV < 15 years</td></tr>
<tr><td>Recycle</td><td>Recycling of kerf
Recovery of polymers from PV module waste for chemical recycling
End-of-Life recycling rate (EOL-RR)</td><td>recovery of about 40% of pure silicon
>90% recovery of EVA, PVF, PVDF and PET
Silicon (90%), Indium (30%), Silver (70%), Cadmium/Tellurium (95%)</td></tr>
<tr><td rowspan="3">Eco-labelling and energy labelling</td><td>Lifetime in Eco-design</td><td>40 years for PV modules
15 years minimum for all electronic / electro-mechanical components of the inverter, including the software needed for the full function of the device.</td></tr>
<tr><td>PV module Degradation rate in Eco- design</td><td>0.4%/year</td></tr>
<tr><td>Delivery of the spare parts</td><td>Within 15 working days within Europe</td></tr>
</table>

	EII classification	> 25 % Products (Modules & Inverters) with a minimum of “B”
	Update of LCI database	Every year
	Milestone	
	Design for deconstruct strategies of tandem technologies, to separate top from bottom cells, and facilitate EoL management At least each individual printed circuit board and disconnectable component of the inverter must be provided as an independent spare part Annual update of the LCI database, including harmonization among the various reference publishers (IEA, ecoinvent, GABI ...)	
Quality assurance to increase lifetime and reliability	Proven lifetime of PV modules through extended testing	40 years
	Accuracy of yield assessments for new technologies and novel system design with uncertainty (1 sigma)	<5%
	Milestone	
	Establishment of European testing capacities for combined or sequential stress tests	
Increase field performance and reliability	Inspected PV plants using (semi)-automatic EL/PL	20 MW/day
	inspected and analyzed PV plants using aerial IR (referring to low-altitude IEC compliant detailed IR inspection)	6 MW/h
	failures or underperformance issues identified (root-cause analyzed) and recovered or isolated;	>90%
	Cost Priority Number of PV system (total cost of O&M, insurance, warranty, etc)	<10 Euro/kWp/year
	Diagnostic accuracy for automated aerial IR imagery: false negatives/positives	<10%
	Diagnostic accuracy: modelled / calculated power loss for automated IR imagery	>95%
	On PV plant level, common annual performance ratio (PR) including periods of unavailability and after correction for expected degradation in the field.	85% for residential and small commercial plants and 90% for other plants
	Proven system energy output per	at least 80% of initial level for 40 years by

	year; (verified by extrapolating performance loss rate analysis and defining contribution at single component level,)	2030 PV module degradation 0.4%/y
	Cost reduction on today's per-schedule preventive or corrective O&M as a result of reducing failures and limiting unnecessary O&M tasks and predictive maintenance	by 10-15%
	Size of large-scale PV performance database	50 GW included in the database with at least 3 years of average operational time by 2025 and 100 GW with at least 7 years of average operational time by 2030
Bankability, warranties and contractual terms	Typical WACC of utility scale PV	Reduced by 1 % compared to base level
	O&M costs	Reduced by 33% thanks to optimisation in contracts
	Milestone	
	Define standardized contractual KPIs for EPC Define the warranty levels of modules, inverters and supporting structures with associated risks	
Ongoing activities		
See **PV Impact database** at https://pvimpact.eu/towards-set-plan-targets-ip-progress/pv-projects-database/		
Outlook and planned activities		

Parties (countries / stakeholders / EU)	**Implementation instruments and Resources**
CET Partnership	Call modules PV2 (Decrease cost of high performance panels and increase lifetime) and OM1/2 (Operation & Maintenance) and SUST1-3 (Sustainability) of the Transition Initiative "Enhanced Zero Emission Power Technologies" (TRI 2)
Horizon Europe	CL5-2022-D3-03-09: Recycling end of life PV modules
National activities	
Belgium	
Cyprus	
France	The activities are promoted by ANR (1) and ADEME. In particular the PEPR TASE(2) and the PIA Investissements d'avenir (3) with the program France 2030 (4) and the announcement of President Macron about 100 GW of Solar PV capacity for France by 2050 (5)

	(1) https://anr.fr/fr/detail/call/programme-solaire-photovoltaique/ (2) https://www.cnrs.fr/fr/pepr/pepr-dacceleration-technologies-avancees-des-systemes-energetiques-tase (3) https://www.enseignementsup-recherche.gouv.fr/fr/investissements-avenir (4) https://www.gouvernement.fr/france-2030 (5) https://www.elysee.fr/front/pdf/elysee-module-19285-fr.pdf
Germany	7. Federal Program on Energy Research, call topics of the BMWK on the improvement of lifetime and quality assurance measures at component and system level and avoidance of hazardous materials and scarce resources.
Italy	
Netherlands	The Dutch Ministry of Economic Affairs and Climate funds RD&I projects first in the mission-oriented programs in which subsequently specific topics for solar PV are articulated. For example in the mission program “on land” (42 TWH in 2030) there is a general topic on circularity, which applies for PV amongst others.
Norway	The Research Council of Norway funds RD&I projects through several funding schemes and calls. The most important schemes for PV-research are the ENERGIX program that supports projects both in the R&D-sector and in industry within renewable energy, energy efficiency, energy system and energy policy and The Centres for Environment-friendly Energy Research (FME) that carry out long-term research targeted towards renewable energy, energy efficiency, CCS and social science aspects of energy research. For more information: Energy, transport and low emissions - portfolio (forskningsradet.no)
Spain	In Spain, the State Plan for Scientific and Technical Research and Innovation 2021-2023 - State Program to Promote Scientific-Technical Research and its Transfer offers support for PV on different levels. It is supplemented by the CDTI – Mission Programme, a challenge-oriented approach programme to support large consortia projects, mainly with a focus on industrial research activities and the CDTI – R&I Projects.
Türkiye	As “Photovoltaic cells, panels and systems” are listed in the “TUBITAK 2022-2023 Priority RDI Themes”, project proposals which targeted above topic are prioritized during the evaluation stage of support programmes. The projects which serve to the objectives of priority RDI themes are supported via TUBITAK 1001 - Scientific and Technological Research Projects Support Program, TUBITAK 1501 - Industry RDI Projects Support Program, TUBITAK 1507 - Initial R&D Support Program for SMEs and TUBITAK 1602 - Patent Support Program. Moreover, the identified priority technologies and applications are also included and supported through the calls of the “Technology-Oriented Industry Move” within the scope of the National Technology Move by the Ministry of Industry and Technology.

4.3. R&I ACTIVITY N. 3 - NEW APPLICATIONS THROUGH INTEGRATION OF PHOTOVOLTAICS

Topic: New Applications through Integration of Photovoltaics (for Diversified and Dual-Use Deployment and Enhanced Value)		
Objectives Physical integration of PV into the built environment, vehicles, landscapes and infrastructures a. PV in buildings b. Vehicle Integrated PV c. Agrivoltaics and landscape integration d. Floating PV e. Infrastructure Integrated PV f. "Low-power" energy harvesting PV		
PV in buildings	Building energy coverage	>50% demand coverage, >30% self-sufficiency, >80% electricity self-consumption
	PV in building costs	cost reduction >50% compared to 2020 levels
	Product lifetime	operational lifetime of PV in buildings' products >35 years
	Circularity	recyclability improved >50% compared to 2020 levels and compatible with building industry standards
VIPV	Vehicle energy coverage	40% average range extension, 50% reduction of charging events
Agrivoltaics and landscape integration	Combined energy and crop yield	should exceed that of either individual use
Floating PV	Costs reduction of floating PV	>50% reduction compared to 2020 levels
	operational lifetime of floating PV	Increase close to or equal to land-based installations (>35 years)
	recyclability	Improve by >50% compared to 2020 levels
Infrastructure integrated PV	Cost reduction	>50% compared to 2020 levels, while maintaining primary function of infrastructure element
	operational lifetime of infrastructure integrated PV	Improve by >80% compared to 2020 levels
	recyclability	Improve by >50% compared to 2020 levels
Low-power energy harvesting PV	Low light conversion efficiency	Improve by >25% on module level in the range 200 lx-500 lx white light illumination
	cost of energy harvester PV	Reduce by >75% compared to 2020 levels

	operational lifetime of energy harvester PV	Increase >5 years
	recyclability	Improve by >50% compared to 2020 levels and compatible with indoor or consumer product standards
Ongoing activities		
See **PV Impact database** at https://pvimpact.eu/towards-set-plan-targets-ip-progress/pv-projects-database/		
Outlook and planned activities		

Parties (countries / stakeholders / EU)	**Implementation instruments and Resources**
CET Partnership	
Horizon Europe	CL5-2022-D3-01-06: Novel Agro-Photovoltaic systems CL5-2022-D3-01-03: Advanced manufacturing of Integrated PV
National activities	
Belgium	
Cyprus	
France	The activities are promoted by ANR (1) and ADEME. In particular the PEPR TASE(2) and the PIA Investissements d'avenir (3) with the program France 2030 (4) and the announcement of President Macron about 100 GW of Solar PV capacity for France by 2050 (5) (1) https://anr.fr/fr/detail/call/programme-solaire-photovoltaique/ (2) https://www.cnrs.fr/fr/pepr/pepr-dacceleration-technologies-avancees-des-systemes-energetiques-tase (3) https://www.enseignementsup-recherche.gouv.fr/fr/investissements-avenir (4) https://www.gouvernement.fr/france-2030 (5) https://www.elysee.fr/front/pdf/elysee-module-19285-fr.pdf
Germany	7. Federal Program on Energy Research, call topic of the BMWK on the development and demonstration of marketable solutions for intelligent sector coupling.
Italy	
Netherlands	The Dutch Ministry of Economic Affairs and Climate funds RD&I projects first in the mission-oriented programs in which subsequently specific topics for solar PV are articulated. For example in the mission program “on land” (42 TWH in 2030) there are solar specific targets for the integration of solar panels into the buildings, infrastructure, vehicles, agriculture, landscape and floating systems.
Norway	The Research Council of Norway funds RD&I projects through several funding schemes and calls. The most important schemes for PV-research are the ENERGIX program that supports projects both in the R&D-sector and in industry within renewable energy, energy efficiency, energy system and energy

	policy and The Centres for Environment-friendly Energy Research (FME) that carry out long-term research targeted towards renewable energy, energy efficiency, CCS and social science aspects of energy research. For more information: Energy, transport and low emissions - portfolio (forskningsradet.no)
Spain	In Spain, the State Plan for Scientific and Technical Research and Innovation 2021-2023 - State Program to Promote Scientific-Technical Research and its Transfer offers support for PV on different levels. It is supplemented by the CDTI – Mission Programme, a challenge-oriented approach programme to support large consortia projects, mainly with a focus on industrial research activities and the CDTI – R&I Projects.
Türkiye	As "Photovoltaic cells, panels and systems" are listed in the "TUBITAK 2022-2023 Priority RDI Themes", project proposals which targeted above topic are prioritized during the evaluation stage of support programmes. The projects which serve to the objectives of priority RDI themes are supported via TUBITAK 1001 - Scientific and Technological Research Projects Support Program, TUBITAK 1501 - Industry RDI Projects Support Program, TUBITAK 1507 - Initial R&D Support Program for SMEs and TUBITAK 1602 - Patent Support Program. Moreover, the identified priority technologies and applications are also included and supported through the calls of the "Technology-Oriented Industry Move" within the scope of the National Technology Move by the Ministry of Industry and Technology.

4.4. R&I ACTIVITY N. 4 - SMART ENERGY SYSTEM INTEGRATION OF PHOTOVOLTAICS

<table>
<tr><td colspan="3">Topic: Smart Energy System Integration of Photovoltaics (for Large-Scale Deployment and High Penetration)</td></tr>
<tr><td colspan="3">Objectives
Energy system integration
a. More intelligence in distributed control
b. Improved efficiencies by integration of PV-systems in DC-networks
c. Hybrid systems including demand flexibility (PV+ Wind + Hydro with embedded storage + batteries + green hydrogen/fuel cells or gas turbines etc.)
d. Aggregated energy and VPPs
e. Interoperability in communication and operation of RES smart grids</td></tr>
<tr><td></td><td>KPI</td><td>Target 2030</td></tr>
<tr><td>Improved efficiencies by integration of PV systems in DC networks</td><td>Hybrid AC / DC energy community systems</td><td>achieve 30% improved efficiencies</td></tr>
<tr><td colspan="3">Ongoing activities</td></tr>
<tr><td colspan="3">See PV Impact database at
https://pvimpact.eu/towards-set-plan-targets-ip-progress/pv-projects-database/</td></tr>
<tr><td colspan="3">Outlook and planned activities</td></tr>
<tr><td>Parties
(countries / stakeholders / EU)</td><td colspan="2">Implementation instruments and Resources</td></tr>
<tr><td>CET Partnership</td><td colspan="2">Call module HYBD1-5 (System integration) of the Transition Initiative “Enhanced Zero Emission Power Technologies” (TRI 2)</td></tr>
<tr><td>Horizon Europe</td><td colspan="2">CL5-2022-D3-01-13: Energy system modelling, optimisation and planning tools</td></tr>
<tr><td>National activities</td><td colspan="2"></td></tr>
<tr><td>Belgium</td><td colspan="2"></td></tr>
<tr><td>Cyprus</td><td colspan="2"></td></tr>
<tr><td>France</td><td colspan="2">The activities are promoted by ANR (1) and ADEME. In particular the PEPR TASE(2) and the PIA Investissements d'avenir (3) with the program France 2030 (4) and the announcement of President Macron about 100 GW of Solar PV capacity for France by 2050 (5)

(1) https://anr.fr/fr/detail/call/programme-solaire-photovoltaique/
(2) https://www.cnrs.fr/fr/pepr/pepr-dacceleration-technologies-avancees-des-systemes-energetiques-tase
(3) https://www.enseignementsup-recherche.gouv.fr/fr/investissements-avenir</td></tr>
</table>

	(4) https://www.gouvernement.fr/france-2030 (5) https://www.elysee.fr/front/pdf/elysee-module-19285-fr.pdf
Germany	7. Federal Program on Energy Research, call topic of the BMWK on next generation of PV power plants.
Italy	
Netherlands	The Dutch Ministry of Economic Affairs and Climate funds RD&I projects first in the mission-oriented programs in which subsequently specific topics for solar PV are articulated. For example in the mission program “on land” (42 TWH in 2030) there is a general topic on system integration which applies for PV amongst others.
Norway	The Research Council of Norway funds RD&I projects through several funding schemes and calls. The most important schemes for PV-research are the ENERGIX program that supports projects both in the R&D-sector and in industry within renewable energy, energy efficiency, energy system and energy policy and The Centres for Environment-friendly Energy Research (FME) that carry out long-term research targeted towards renewable energy, energy efficiency, CCS and social science aspects of energy research. For more information: Energy, transport and low emissions - portfolio (forskningsradet.no)
Spain	In Spain, the State Plan for Scientific and Technical Research and Innovation 2021-2023 - State Program to Promote Scientific-Technical Research and its Transfer offers support for PV on different levels. It is supplemented by the CDTI – Mission Programme, a challenge-oriented approach programme to support large consortia projects, mainly with a focus on industrial research activities and the CDTI – R&I Projects.
Türkiye	As “Photovoltaic cells, panels and systems” are listed in the “TUBITAK 2022-2023 Priority RDI Themes”, project proposals which targeted above topic are prioritized during the evaluation stage of support programmes. The projects which serve to the objectives of priority RDI themes are supported via TUBITAK 1001 - Scientific and Technological Research Projects Support Program, TUBITAK 1501 - Industry RDI Projects Support Program, TUBITAK 1507 - Initial R&D Support Program for SMEs and TUBITAK 1602 - Patent Support Program. Moreover, the identified priority technologies and applications are also included and supported through the calls of the “Technology-Oriented Industry Move” within the scope of the National Technology Move by the Ministry of Industry and Technology.

4.5. R&I ACTIVITY N. 5 - SOCIO-ECONOMIC ASPECTS OF THE TRANSITION TO HIGH PV CONTRIBUTION

Topic: Socio-Economic Aspects of the Transition to High PV Contribution		
Objectives 1. Higher awareness of solar PV-related externalities and benefits 2. Economic & sustainability benefits		
	KPI	Target 2030
Developing a PV hotbed for urban implementation	Share of PV on total electricity generation	
	Share of PV of total energy generation	
Ongoing activities		
See **PV Impact database** at https://pvimpact.eu/towards-set-plan-targets-ip-progress/pv-projects-database/		
Outlook and planned activities		

Parties (countries / stakeholders / EU)	**Implementation instruments and Resources**
CET Partnership	Call module REG1/2 (Pre-normative research) of the Transition Initiative “Enhanced Zero Emission Power Technologies” (TRI 2)
Horizon Europe	
National activities	
Belgium	
Cyprus	
France	The activities are promoted by ANR (1) and ADEME. In particular the PEPR TASE(2) and the PIA Investissements d'avenir (3) with the program France 2030 (4) and the announcement of President Macron about 100 GW of Solar PV capacity for France by 2050 (5) (1) https://anr.fr/fr/detail/call/programme-solaire-photovoltaique/ (2) https://www.cnrs.fr/fr/pepr/pepr-dacceleration-technologies-avancees-des-systemes-energetiques-tase (3) https://www.enseignementsup-recherche.gouv.fr/fr/investissements-avenir (4) https://www.gouvernement.fr/france-2030 (5) https://www.elysee.fr/front/pdf/elysee-module-19285-fr.pdf
Germany	7. Federal Program on Energy Research – part of the work within the BMWK research network on PV.
Italy	
Netherlands	The Dutch Ministry of Economic Affairs and Climate funds RD&I projects first

	in the mission-oriented programs in which subsequently specific topics for solar PV are articulated. For example in the mission program “on land” (42 TWH in 2030) there is a general topic on social acceptability which applies for PV amongst others.
Norway	The Research Council of Norway funds RD&I projects through several funding schemes and calls. The most important schemes for PV-research are the ENERGIX program that supports projects both in the R&D-sector and in industry within renewable energy, energy efficiency, energy system and energy policy and The Centres for Environment-friendly Energy Research (FME) that carry out long-term research targeted towards renewable energy, energy efficiency, CCS and social science aspects of energy research. For more information: Energy, transport and low emissions - portfolio (forskningsradet.no)
Spain	In Spain, the State Plan for Scientific and Technical Research and Innovation 2017-2020 - State R+D+I Program Oriented to the Challenges of Society offers support for PV as well.
Türkiye	As “Photovoltaic cells, panels and systems” are listed in the “TUBITAK 2022-2023 Priority RDI Themes”, project proposals which targeted above topic are prioritized during the evaluation stage of support programmes. The projects which serve to the objectives of priority RDI themes are supported via TUBITAK 1001 - Scientific and Technological Research Projects Support Program, TUBITAK 1501 - Industry RDI Projects Support Program, TUBITAK 1507 - Initial R&D Support Program for SMEs and TUBITAK 1602 - Patent Support Program. Moreover, the identified priority technologies and applications are also included and supported through the calls of the “Technology-Oriented Industry Move” within the scope of the National Technology Move by the Ministry of Industry and Technology.

5. ANNEX II – MEMBERS OF THE IWG

Member States (10)

member		alternate
Belgium - Walloon region	Laurence Polain	
Belgium - Flemish region	Lut Bollen	
Cyprus - University of Cyprus	George E. Georghiou	Aris Bonanos
France - Institut Photovoltaique d'Ile de France - IPVF, CNRS, Ecole Polytechnique	Pere Roca i Cabarrocas	
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	Birgit Hernes
Spain - Centre for the Development of Industrial Technology (CDTI)	Luisa Revilla Trujillo	Cristina Trueba
Türkiye - TUBITAK	Cagri Yildirim	Hanife Tuzcuoglu

European Commission

member	
DG RTD	Maria Getsiou
DG ENER	N.N.
EC JRC	Arnulf Jäger-Waldau

ETIP PV & Industry (10)

member	
Becquerel Institute	Gaëtan Masson
EERA PV (IMEC)	Ivan Gordon
EERA PV (Fraunhofer ISE)	Simon Philipps
Enel Green Power	Fabrizio Bizzarri
EURAC	David Moser (Co-Chair)
EUREC / ETIP PV Secretariat	Greg Arrowsmith
HZB Helmholtz-Zentrum Berlin and ETIP PV	Rudger Schlatmann
IMEC	Jef Poortmans
SETA Network	Silke Krawietz
University of Ljubljana	Marko Topič

6. ANNEX III – STATISTICAL BUDGET DATA

From PV Impact report:

Deliverable 4.3: Summary of the nature of PV research funded in Europe

Source: https://pvimpact.eu/news-resources/reports/download/summary-of-the-nature-of-r-d-research

Country	(1) PV impact TOTAL Budget (2016-2020) [M€]	(2) IEA ref 2016-2020 [M€]	(3) % budget from IEA ref	(4) Average annual Budget per capita [€ per capita/year]	(5) Aver. annual Budget vs GDP [€ / M€GDP/year]
Austria	12.0	43.7	27.6%	0.27	6.06
Belgium	4.7	25.2	18.8%	0.08	1.98
Bulgaria	0.2			0.01	0.61
Cyprus	3.5			0.80	30.77
Czech Republic	0.0	1.2	0.0%	0.00	0.00
Denmark	0.1	14.6	0.7%	0.00	0.07
Estonia	0.0	1.6	0.0%	0.00	0.00
Finland	1.3	27.4	4.7%	0.05	1.08
France	55.0	357.9	15.4%	0.16	4.51
Germany	400.4	433.5	92.4%	0.96	23.05
Greece	0.5			0.01	0.56
Hungary	0.0	0.2	0.0%	0.00	0.00
Ireland	0.0	2.1	0.0%	0.00	0.00
Israel	3.1			0.07	
Italy	73.8	104.4	70.7%	0.25	8.22
Netherlands	46.4	113.0	41.1%	0.54	11.42
N. Macedonia	0.1				
Norway	2.8	57.6	4.9%	0.11	1.57
Poland	0.6	24.8	2.4%	0.00	0.23
Portugal	0.5			0.01	0.43
Slovakia	0.0	1.7	0.0%	0.00	0.00
Slovenia	0.1			0.01	0.41
Spain	11.5	67.7	17.0%	0.05	1.85
Sweden	2.9			0.06	1.20
Switzerland	29.5	165	17.9%	0.69	9.03
Turkey	1.2	12	10.0%	0.00	0.36
United Kingdom	3.0	185	1.6%	0.01	0.24
Transnat.	5.4				
Grand Total	**658.8**	**1595.2**	**41.3%**	**0.23**	**7.54**

(1) captured PV R&D budget for the 2016-2020 range by the PV impact database [M€]
(2) IEA research RD&D budget for the same time period [M€]
(3) % of RD&I budget captured by PV IMPACT as compared to overall RD&I budget for the PV sector, as extracted from the IEA database for PV related project[15](in grey countries with missing data) [%]
(4) Average annual PV R&D budget (captured by the PV impact database between 2016-2020) per capita [in € per person per year]
(5) Average annual PV R&D budget (captured by the PV impact database between 2016-2020) as a function of the national GDP in 2019 [in € per million€ GDP per year]

IMPRINT

Published by:
European Strategic Energy Technology Plan (SET Plan),
Implementation Group for Photovoltaics (IWG PV)

Responsible:
Implementation Group for Photovoltaics (IWG PV)

Edited by:
Project Management Jülich (PtJ)