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PV IMPACT

Actual execution of the Implementation Plan for Photovoltaics and monitoring the Implementation Plan's delivery

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Deliverable 4.4: Monitoring report on metrics and gaps

Lead beneficiary: EURAC

Disclaimer of warranties

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About PV IMPACT

PV IMPACT will try out a variety of approaches to stimulate PV research, development and innovation initiatives in Europe. The first part of the project will focus on inviting companies to matchmaking events so they can find partners with whom to work on future projects under EU and/or national funding schemes. The project will also target two specific industrial companies: ENEL Green Power and Photowatt. Another important part of the project will be to monitor progress in PV. Data will be collected on public spending in the EU, on private spending, on the kinds of projects being funded and on the overall performance of PV technology. Forecasts for future spending will be made according to various scenarios. The project will track whether improvements in the performance of technology are keeping pace with expectations and will make recommendations to European funding authorities.

PV IMPACT Partners

Document information

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Lead author/s	David Moser (EURAC)
Contributors	

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Dissemination level

PU	Public	X
RE	Restricted to a group specified by the Consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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1. Introduction

This deliverable is an integral part of Work Package 4, which focuses on Monitoring of R&I activities for the execution of the SET Plan Implementation Plan-PV and aims to generate the knowledge on the status of the SET Plan targets. Specifically, this deliverable reflects activities in Task 4.4, which focuse on Monitoring metrics on the state of PV technology. The IWG-PV has set the overall metrics for technology and economic performance that are to be monitored within the PV Implementation Plan. The role of PV IMPACT is to monitor the research being done in PV sector and provide feedback on the chosen metrics as well as defining additional detailed metrics as appropriate. This includes looking at the ability of PV sector to meet the targets of the Declaration of Intent, reviewing its relevance to Implan, and, where possible, at the position of technology made-in-Europe in these KPIs. Progress in Europe will be distinguished, where possible, from progress made worldwide.

2. Objectives

- To support the IWG in choosing the appropriate metrics for the 6 activities included in the PV Implementation Plan
- To monitor the progress in reaching the set targets for the metrics
- To suggest more detailed metrics if needed

3. Target groups and stakeholders

The main target group is the Implementation Working Group (IWG-PV). The EU ETIP-PV has been constantly addressed also to receive feedback. Since early 2021, EURAC, EUREC, BI and WIP had monthly meetings with the IWG-PV Secretariat.

4. Metrics

The IWG and PV Impact are in contact to provide the needed support in the definition of the metrics and indicators. A dedicated meeting was held in Brussels on the 10th of October 2019 and the main outcome was the following:

Table 1: Table as received from IWG with suggested metrics

IP Activity		DoI - key-words	IP - suggested monitoring mechanism
No	**Activity**		

1	**PV for BIPV and similar applications**	decrease additional cost for BIPV's main applications	market size and application prices for integrated PV at the start (2017) and finish (2020) for each PMC (product market combination), estimated added surface otherwise unused for PV, cost reduction of integrated PV solution by square meter
2	**Technologies for silicon solar cells and modules with higher quality**	increase PV module efficiency, further enhancement of lifetime, quality and sustainability	increase cell efficiency in industrial environment, as well as module efficiency and module lifetime
3	**New Technologies & Materials**	increase PV module efficiency, further enhancement of lifetime, quality and sustainability	increase efficiency targets above limits of existing individual PV technologies
4	**Operation and diagnosis of photovoltaic plants**	./.	on PV plant level, achieve common annual performance ratio (PR)
5	**Manufacturing technologies**	increase PV module efficiency, further enhancement of lifetime, quality and sustainability	reduction of the module manufacturing cost (of ownership; CoO) by reducing equipment (CAPEX) and material cost (BOM)
6	**Cross-sectoral research at lower TRL**	./.	number of collaborations of national labs and resulting co-operations with industry

Table 2: Comments provided to IWG and level of support to monitor metrics

No	**PV IMPACT support**	**General Comments PV IMPACT August/September 2019**	**Comments meeting IWG/PV IMPACT 10th October 2019**	**lead**	**Update 02/2020**
1	access to country data	Data in available market reports is questionable, with limited to no vision on the methodology and the sources.	Cross check market values from industry and from countries / differentiate between applications	EURAC	No updates
2	Enel Green Power and Photowatt efficiency values. Get in contact with smaller manufacturers through surveys (also consider thin film		Lifetime. How are we going to measure it? / Global benchmark and EU benchmark / include also other technologies (2b) / should we include other parameters such as LCA?	Process in // IWG + PV Impact	24.63% record cell level EGP. At module level the record efficiency EGP obtained is 393W even if they obtained some new result above 400W using M2 wafers. An extrapolation to new standards for wafers EGP can consider for the near future for M6 wafer 440W (using 393 as reference) and for M12 (150 slice of 1/3 of M12 wafers) up to 500W (always using 393 as reference).

	technologies), manufacturers in IWG.				Concerning Photowatt, the current maximum efficiency (available on datasheets): - On 60 (120 half cells) modules : 315 Wp - On 72 (144 half cells) modules : 380 Wp. This corresponds to an area efficiency of around 190 Wc/m².
3	Support from ISE and IMEC to map this target R&D center well known for record high efficiency in specific technologies		OK. EERA will help	EERA-PV	No updates
4	Report from 3E on increasing PR from their dataset. EURAC in Task 13 and PEARL PV. Roadmap to increase PR? Ask 3E, provide indication PR in portfolio. Task13 database of PR performance		EURAC will try to run statistical analysis. We have some plots	EURAC	Plots from T13 are available. We are trying to get similar plots from other initiatives. 3E is willing to support this activity by providing plots from their portfolio of monitored systems

5	ITRPV defines these numbers in a clear way (10.10.19). Only Silicon / CIGS will have to be done directly with selected manufacturers	As for activities 2 and 3, it would make sense to cover cells in addition to modules. We could even consider wafer manufacturing, which remain at the core of the value chain. As long as the production of wafers is out of the hand of EU manufacturers, competitiveness of final products can be threatened. This would even make more sense if we decide to include "environmental footprint" aspects. Also, we agree that it would make sense to focus on the situation of EU-made products, and to establish an international benchmark for comparison			

6	this could come out as output of T4.2 look at literature, authors to show collaboration between centres and industry (10.10.19)				

During 2020, PV IMPACT received further comments from the ETIP-PV and PV IMPACT consortium members and are here summarised. The authors of the comments are kept anonymous. No comments were provided for IP5 (Manufacturing technologies).

Table 3: comments received from the iterations between ETIP-PV and PV IMPACT for the various activities of the implementation plan

IP 1 BIPV Comments 2020		
Comment	Suggested KPI	General comment
1	Cost reduction and market size increase	Distinguish between well-defined different product types to make it easier to get an overview and to see trends in specific market segments
2	PV for BIPV and similar applications	Distinguish between prices and costs. Cost reduction = Price in the market reduction
3	Access to country data	Use public reports of recent projects on BIPV focused on cost reduction, e.g. BIPVBOOST.
4	Market based on BIPV categories	We may need to define (different) categories in BIPV to usefully quantify cost (differences) as well as volume added. E.g. Integrated roofs of family houses, office facades, etc.

IP 2 Si cells and modules Comments 2020		
Comment	Suggested KPI	General comment
1	Lifetime warranty provided by module producers	
2	Average module efficiency being sold	Although the target is to increase cell and module efficiency, I do not know if we have to monitor cell efficiency separately since in the end the module is the final product. Module efficiency will also benefit from higher cell efficiencies.
3	Lifetime, efficiency (cell and module)	ITRPV could be a good input
4	Values of LCA, EPBT, Lifetime, etc taken from updated literature review	Difficult to make general statements on proven lifetimes, especially for relatvely new technologies. Warrantees given my be an indicator. LCA is even more complex for a monitoring effort. Perhaps an annual literature review of EPBT, eco-design, etc. is useful. Many data required are company-confidential.

IP 3 New technologies Comments 2020		
Comment	Suggested KPI	General comment
1	Record efficiencies of novel technologies as a function of area	e.g. 2T, 4T tandems, perovskite monojunction cells, ...
2	Record efficiency of novel technologies Accelerated lifetime testing results from literature review regularly updated	KPIs must be chosen to allow for comparison. E.g, (lab/pilot production) efficiencies of perovskites, hybrid tandems, etc. and larger areas (submodules, prototype modules, etc.), should be monitored separately and not compared with commercial Si or TF modules. Concerning lifetime, etc.: make a regular literature review and overview of e.g. accelerated lifetime test results, for instance.

IP 4 Operation and Diagnosis Comments 2020		
Comment	Suggested KPI	General comment
1	Performance Loss Rate	Performance Loss Rate reported in the literature for various systems (not only depending on modules) in various climates
2	PV Plant unavailability	Values provided by O&M portfolio holders or providers of monitoring solutions
3	WACC (bankability)	Lower WACC due to improved O&M, especially in large-scale PV plants
4	Average Specific Yield per technology, climate and system configuration	In addition to performance ratio, specific yield (kWh/kWp per year) should be included, especially since bifacial and various tracking designs and concepts are now rapidly gaining market interest.

IP 6 Cross sectoral low TRL Comments 2020		
Comment	Suggested KPI	General comment
1	Number of publications from European researchers on Low TRL PV related topics	Will be very difficult to obtain
2	Identify 3 case studies per year	Regularly collect e.g. 3 exemplary cases/ success stories of such cross-sectoral low-TRL research. One may think of perovskites/ EPKI, novel business models or advanced light management, and many other topics.

5. Targets

The IWG has set targets for the various KPIs included in the PV Implementation Plan. PV IMPACT collected comments which were added to the table below.

Table 4: Iterations process between IWG, PVIMPACT and ETIP-PV about the 2020 and 2030 targets

Statement		**IWG Remarks**	**Comments PV IMPACT**
Initial Targets	**Revised Targets**		
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	<no changes > ETIP-PV comment: Revision of efficiency and time target needed. Initial target has been more than-fulfilled, 2020 has come.	2015 the module power for different c-Si cell types (60 cells per module, p-type material – still mostly used material) ranged from 265 to 285 W (see ITRPV April 2015). The ITRPV 2019 shows numbers from 280 to 320 W for standard p-type cells thus resulting in an increase of efficiency of 9%. Currently, first 60 cell modules with efficiencies around 355 W are offered (i.e LG 356 W, Trina 355 W); this means an increase of 29%.	The average module efficiency did not increase by 20%, but with the transition to PERC we are seeing already in 2020 high increase. PV IMPACT suggestion is not to reduce the target for 2020 now. The target was a bit too ambitious for mainstream modules (although there are modules in the market which goes beyond 20% improvement). Modules with higher efficiency increase are, however, now easily available on the market already and will become standard soon. The upgrade of production lines takes longer than 5 years, in particular taking into account the price competition and limited investment funds of the PV manufacturers in the last five years. Hence 20% in 5 years was really ambitious. 24.63% record cell level EGP. At module level the record efficiency EGP obtained is 393W even if they obtained some new result above 400W using M2 wafers. An extrapolation to new standards for wafers EGP can be considered for the near future for M6 wafer 440W (using 393 as reference) and for M12 (150 slice of 1/3 of M12 wafers) up to 500W (always using 393 as reference). Concerning Photowatt, the current maximum efficiency (available on datasheets): - On 60 (120 half cells) modules : 315 Wp - On 72 (144 half cells) modules : 380 Wp. This corresponds to an area efficiency of around 190 Wc/m².

Increase PV module efficiency by at least 35% by 2030 compared to 2015, including with the introduction of novel PV technologies	<no changes> EITP PV: Analysis of actual and projected module efficiency needed, with 400 W modules today, the initial target has been fulfilled. Efficiency target of 2030 needs revision.	For 2030 (see ITRPV 2019 estimates for 2029) standard modules of 365 to 375 W could be feasible, resulting in a module efficiency increase of 37%. It is suggested to maintain the current target as it states an increase of “at least” 35%.	With respect to the efficiency targets, PV IMPACT agrees to the remarks made for the 2030 target: +35% compared to 2015 is still valid and agrees with the ITRPV.
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 50% by 2020 as compared to 2015 ETIP PV: assessment needed, whether revised target will be fulfilled in 2020. In any case, revision needed (2020 is there).	ITRPV 2015 shows system costs for large PV systems > 100 kWp of roughly 1.200 US$/kWp; the 2019 report gives a number of 0.63 US$/W(DC) for 2019. From this data, a rough estimation of system costs reduction results in 50%.	For the turn-key system cost reduction we see a decrease of 50% from 2015 to 2020.
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	Reduce turn-key system costs by at least 60% by 2030 compared to 2015 with the introduction of novel, potentially very-high-efficiency PV technologies	For 2029, ITRPV foresees system prices of 0.45 US$/W(DC) which would show a reduction by more than 60% compared to 2015	For 2030 however, we aim at a cost reduction of 60% compared to 2015, hence only another 10% reduction in 1o year time based on the introduction of novel technology as explicitly stated. This does not seem ambitious enough at all as target for a technology implementation plan for the next 10 years. I think we should aim at least at a 70-75% reduction in 2030.

	manufactured at large scale		
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;	<no changes >	on module level, performance warranty still covers only 25 years and degradation per year during performance warranty amounts to around 0.7% (data from IRPV 2019) resulting at 84% of initial level after 25 years	Degradation at system level per year found in literature varies from study to study. Lindig et al[1] looking at the IEA Task 13 PVPS Performance data have calculated an annual system performance loss rate of -0.51%, -0.60%, -0.99% for mono, poly Silicon and thin film respectively using the Year on Year methodology. The average operational months were 62, 66 and 91, respectively. The analysis included 120 PV systems with more than 90% located in Europe. This would translate to a range of -15.3% - -29.7% over 30 years for systems installed before 2015. Target for 2020 can be considered as achieved and the target for 2025 can be kept. 3E is willing to support this activity by providing plots from their portfolio of monitored systems
Minimize life-cycle environmental impact along the whole value chain of PV electricity generation, and increase recyclability of system components (in particular: of modules)	<no changes> ETIP PV: Is there any qualitative statement possible?		

[1] Performance Loss Rates of PV systems of Task 13 database, IEEE PVSC 2019, Lindig et al

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	<no changes> ETIP PV: quantitative target possible?		
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	<no changes > ETIP PV: The 2020 target needs to be checked quantitatively and revised (since 2020 is there). If quantitative evidence is not possible (maybe due to still not existing mature market), another criteria is needed. 2030 target has to checked in the light of this analysis.	BIPV is still a niche market throughout Europe	H2020 projects like BIPVBOOST will help in monitoring this metric (EURAC, WIP and BI are partners) PV development is more and more application driven and there are more and more diverse applications, not only BIPV, but also VIPV, floating PV, etc. There are also more and more projects being funded on integrating PV systems with electrolysers to generate hydrogen or other chemicals/fuels. All this is completely lacking in the targets. Hence, we should consider to “break open” the BIPV centered target towards more in general PV applications beyond the traditional BAPV and PV power plants.
Recognize the importance of aesthetics in the activities of the implementation of NZEB;	<no changes>		At EURAC they have developed a website www.bipv.eurac.edu which could be used to this purpose. SUPSI has similar activity at the website https://solarchitecture.ch/
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	<no changes>	Currently, most of the PV cells and modules are imported from Asia. Although manufacturing machines and lines are being developed on a high level in Europe, competition with oversea companies is increasing. The cell efficiencies are increasing steadily, the costs are reduced, and therefore the challenge of keeping up with high-throughput and cost efficient equipment is continuing. In addition: Higher cell efficiencies are partially based on new cell structures and new production processes (e.g. passivated contacts or tandem cells), which are currently demonstrated in research institutes and industry laboratories. New industrial processes and large scale equipment has to be developed to bring theses cell concepts into economically interesting mass production .	

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	**ETIP PV: Assessment of situation in 2020 needed. Target needs revision at least in time line.**	PV system installation costs for systems > 100kW in the U.S. and Europe amounted to 16% of the overall system costs in 2015. For 2019, this share amounts to 19% for Europe but on a significant lower level. In absolute numbers, system installation costs lowered from around 190 US$/W to 120 US$/W (all data from ITRPV 2015 and 2019). Consequently, for ground ground-mounted systems a revision of targets seems worth to consider. However, innovative solutions are needed for BIPV.	

On the 12th of May 2020, PV IMPACT was invited to the periodic IWG meeting to report on the targets and to propose a method to update the values. PV IMPACT provided as content for the discussion the previous tables and the following feedback. No comments or feedback were gathered for PV manufacturing. The underperforming target were highlighted in red, the overperforming in green under the headings “Monitoring 2020”.

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

Table 5: Monitoring 2020 with under and overperforming targets and proposed values for monitoring

Statement	PV IMPACT 12 May 2020	Monitoring 2020
Initial Targets		
Increase PV module efficiency by at least 20% by 2020 compared to 2015 levels	Problem: comments are pointing in different directions. For some we already reached the 2020 targets, for others we are close but not completely achieved. What are the 2015 levels? Have we agreed on the values? PROPOSAL: We define a reference value for 2015 (270-330 W provided by ITRPV 2015, values not given using module area, if we use 1.65 m2 we obtain 165-200 W/m2 centered around 175 W/m2). We define reference values for 2020 (using module area 190 to 215 W/m2 directly provided by ITRPV 2020, centered around 200 W/m). The module efficiency increase would be around 15%. The suggestion is not to reduce the target for 2020 now. The target was a bit too ambitious for mainstream modules	15%

	although there are modules in the market which goes beyond 20% improvement.	
Increase PV module efficiency by at least 35% by 2030 compared to 2015, including with the introduction of novel PV technologies	Problem: depending on what we will consider as standard in 2020, we will have to either keep or update 2030 target PROPOSAL: Once agreed on the set of reference products for 2020 we can discuss whether 35% is ok or should be increased. (2030 ITRPV module area efficiency centered around 230 W/m2. Around 30%)	30%

Reduction of the cost of key technologies

Statement		PV IMPACT 12 May 2020	PV IMPACT position	Monitoring 2020
Initial Targets	**Revised Targets**			
Reduce turn-key system costs by at least 20% by 2020 as compared to 2015	Reduce turn-key system costs by 50% by 2020 as compared to 2015	Problem: we need to clearly identify 2015 refence value. Do we differentiate by market segment? PROPOSAL: PV IMPACT will propose reference values at market segment level (use papers Vartiainen et al)	Values turnkey CAPEX from LCOE ETIP PV WG for 2020 utility scale: 0.42 Euros/Wp (0.8 in 2014) 47% reduction residential system 5 kWp: 1.1 euros/Wp (1.64 in 2014) 33% reduction commercial system 50 kWp: 0.7 Euros/Wp (1.32 in 2014) 47% reduction Industrial 1 MWp: 0.5 Euros/Wp (0.95 in 2014) 47% reduction Values PV average module price	Residential 30% Commercial 45% Industrial 45% Utility scale 45%

			utility scale: 0.17 Euros/Wp 2020 (0.45 in 2014) residential/commercial: (0.61 in 2014)	
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	Reduce turn-key system costs by at least 60% by 2030 compared to 2015 with the introduction of novel, potentially very-high-efficiency PV technologies manufactured at large scale	Problem: The target mentions 'novel technologies', which may be different from what the ITRPV refers to? More clarity is needed PROPOSAL: To be discussed based on 2020 final value	Cost and prices are not clearly distinguished, which should be corrected with priority. Further, typical, average or lowest are terms that play in the background. For new technologies, their prices at market introduction are not indicative for their potential, so make a separate category, incl. their cost potential at high volume? From ETIP PV WG LCOE 2030 base volume growth scenario utility scale: 0.3 Euros/Wp (0.8 in 2014) 63% reduction residential system 5 kWp: 0.75 euros/Wp (1.64 in 2014) 55% reduction commercial system 50 kWp: 0.45 Euros/Wp (1.32 in 2014) 65% reduction Industrial 1 MWp: 0.35 Euros/Wp (0.95 in 2014) 63% reduction	Residential 55% Commercial 65% Industrial 65% Utility scale 65%

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:

Statement	PV IMPACT 12 May 2020	ETIP PV Comments
Initial Targets		
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	PROPOSAL: Close feedback with proposal funded through the H2020 RES 6 calls. BE-SMART, BIPVBOOST and PVAdapt where cost reduction was stated in the call.	In the case of PV for diverse applications, the target wouldn't be so much focused on the cost reduction, but in making the integration and adaptation possible. Cost reduction is valid for BIPV, but maybe not for VIPV.
Recognize the importance of aesthetics in the activities of the implementation of NZEB;	PROPOSAL: Monitor number of demo cases included in available databases where aesthetics play a role	

Further enhancement of lifetime, quality and sustainability and hence improving environmental performance

Statement	PV IMPACT 12 May 2020	Monitoring 2020
Initial Targets		
Maintain proven system energy output per year at least 80% of initial level for 30 years by 2020 and for 35 years by 2025;	PROPOSAL: extrapolation from performance loss rate shows that the targets are achievable. We need to show that there is a trend in decreasing PLRs. PV IMPACT will provide an analysis of current trends and propose 2030 targets.	2020 70% - 85% of initial level tending more towards 85%
Minimize life-cycle environmental impact along the whole value chain of PV electricity generation, and increase recyclability of system components (in particular: of modules)	PROPOSAL: PV IMPACT will follow the output of the outcome of WG5 ETIP PV work and will report back by December 2020	To be discussed
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	PROPOSAL: PV IMPACT will follow the output of the outcome of WG5 ETIP PV work and will report back by December 2020	To be discussed

6. The Strategic Research and Innovation Agenda for PV

In January 2021, the ETIP-PV has started the process of drafting the SRIA-PV which was presented and opened to the public consultation during the annual ETIP-PV conference on the 19th-20th of May. The SRIA has produced a vast amount of KPIs and targets for 2030 which could be considered by the IWG for the update of the Implementation Plan.

The SRIA is divided in 5 main challenges:

Challenge 1: Performance enhancement and cost reduction

Challenge 2: Enhancing Lifetime, Reliability and Sustainability

Challenge 3: Diversified Application and Integration

Challenge 4: Smart Energy System Integration

Challenge 5: Socio-Economic Aspects of the Transition

The challenges can be mapped to the Activities of the Implementation Plan as following:

Table 6: Mapping of IP activities and SRIA challenges

	BIPV	Si cells and modules	New technologies	Operation and Diagnosis	Manufacturing	Cross-sectoral low TRL
Challenge 1: Performance enhancement and cost reduction		x	x	x	x	x
Challenge 2: Enhancing Lifetime, Reliability and Sustainability		x		x	x	x
Challenge 3: Diversified Application and Integration	x					x
Challenge 4: Smart Energy System Integration				x		x
Challenge 5: Socio-Economic Aspects of the Transition						

Below, the main KPIs and Targets from the SRIA are reported. The most relevant for the 6 activities of the IP are highlighted in yellow.

Table 7: List of KPIs from the ETIP-PV SRIA as per 1 June 2021

<table>
<tr><th></th><th>KPI</th><th>Target 2030</th></tr>
<tr><td rowspan="5">Challenge 1
Silicon PV Modules</td><td>silicon-based cell and module manufacturing capacity with low carbon footprint in Europe</td><td>100 GWp</td></tr>
<tr><td>LCoE in Europe</td><td>0.025 €/kWh for utility-scale PV
<0.05 €/kWh for Integrated Photovoltaic elements</td></tr>
<tr><td>Module conversion efficiency</td><td>25%</td></tr>
<tr><td>Module lifetime</td><td>50 years</td></tr>
<tr><td>Energy ROI</td><td>50 in Southern Europe</td></tr>
<tr><td rowspan="3">Challenge 1
Perovskite PV modules</td><td>LCoE of Pk-PV technology</td><td>Equal to or lower than that for c-Si</td></tr>
<tr><td>The yield-specific CO2 footprint of Pk-PV technologies</td><td><80% of c-Si production and modules should be fully recyclable.</td></tr>
<tr><td>Commercially available, Pk-based module efficiency</td><td>>23%</td></tr>
<tr><td rowspan="3">Challenge 1
thin-film (non-perovskite) PV modules</td><td>LCoE of thin-film technology</td><td>Equal to or lower than that for c-Si</td></tr>
<tr><td>Indium or tellurium reduction</td><td>Factor 3 per W</td></tr>
<tr><td>global market share for thin-film-based modules</td><td>10%</td></tr>
<tr><td rowspan="3">Challenge 1
Tandem-PV modules</td><td>Efficiency</td><td>at least 5% absolute above respective single junction technology</td></tr>
<tr><td>Lifetime</td><td>at par with respective single junction technology</td></tr>
<tr><td>Production cost of additional junction</td><td>less than 8 €/m2</td></tr>
<tr><td>Challenge 1</td><td>BOS components operational lifetime of complete PV systems</td><td>50 years</td></tr>
</table>

Balance of System and energy yield 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
Challenge 1 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.	
Challenge 1 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.	
Challenge 2 Reduce	Energy required to produce MGS	< 20 kWh/kg (current value 32 kWh/kg)
	Carbon footprint	PV tandem system < 40 g CO2-eq/kWh, thin film single junction < 20 g CO2-eq/kWh
	Primary raw material usage for BOS i.e., concrete and steel	Reduction by at least 3% (4% reduction by 2030 and further 6-7% by 2050)
	Primary raw material usage	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)
	Acquisition of PV materials from European producers	Increase silicon metal by 20% (Norway, 6% global share in 2019), and silver by 30% (Poland, 20% global share in 2019)
Challenge 2 Reuse	% repair/reuse after EoL of first life PV	>50%
	years of operation for reused modules	>10 years
	cumulative lifetime minimum	40 years
	Milestone	
	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	
Challenge 2 Recycle	Recycling of kerf	recovery of about 40% of pure silicon
	Recovery of polymers from PV module waste for chemical recycling	>90% recovery of EVA, PVF, PVDF and PET

	End-of-Life recycling rate (EOL-RR)	Silicon (90%), Indium (30%), Silver (70%), Cadmium/Tellurium (95%)
Challenge 2 Eco-labelling and energy labelling	Lifetime in Eco-design	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.
	PV module Degradation rate in Eco-design	0.4%/year
	Delivery of the spare parts	Within 15 working days within Europe
	EII classification	> 25 % Products (Modules & Inverters) with a minimum of "B"
	Update of LCI database	Every year
	Milestones	
	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 ...)	
Challenge 2 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	
Challenge 2	Inspected PV plants using (semi)-automatic EL/PL	20 MW/day

Increase field performance and reliability		
	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 year; (verified by extrapolating performance loss rate analysis and defining contribution at single component level,)	at least 80% of initial level for 40 years by 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
Challenge 2 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
	Milestones	
	Define standardized contractual KPIs for EPC	
	Define the warranty levels of modules, inverters and supporting structures with associated risks	
Challenge 3 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
Challenge 3 VIPV	Vehicle energy coverage	40% average range extension, 50% reduction of charging events
Challenge 3 Agrivoltaics and landscape integration	Combined energy and crop yield	should exceed that of either individual use
Challenge 3 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

Challenge 3 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
Challenge 3 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
Challenge 4 Improved efficiencies by integration of PV systems in DC networks	Hybrid AC / DC energy community systems	achieve 30% improved efficiencies
Challenge 5 Developing a PV hotbed for urban implementation	Share of PV on total electricity generation	
	Share of PV of total energy generation	

The KPIs highlighted in yellow are mapped in the following tables with a link with the relevant IP activity.

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

IP	SRIA
Increase PV module efficiency by at least 35% by 2030 compared to 2015, including with the introduction of novel PV technologies (2015 ITRPV 17.5%, 2030 ITRPV module area efficiency centered around 23%, 30% increase)	Silicon PV: Module conversion efficiency 25% (>40% increase)
	Commercially available, Pk-based module efficiency >23%
	Tandem technology: Efficiency at least 5% absolute above respective single junction technology

Reduction of the cost of key technologies

IP	SRIA
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	LCoE in Europe 0.025 €/kWh for utility-scale PV <0.05 €/kWh for Integrated Photovoltaic elements
	LCoE of Pk-PV technology Equal to or lower than that for c-Si
	Production cost of additional junction less than 8 €/m2

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:

IP	SRIA
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	PV in building costs cost reduction >50% compared to 2020 levels

Recognize the importance of aesthetics in the activities of the implementation of NZEB;	
	Building energy coverage: >50% demand coverage, >30% self-sufficiency, >80% electricity self-consumption

Further enhancement of lifetime, quality and sustainability and hence improving environmental performance

IP	SRIA
Maintain proven system energy output per year at least 80% of initial level for 30 years by 2020 and for 35 years by 2025;	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 year; (verified by extrapolating performance loss rate analysis and defining contribution at single component level,) at least 80% of initial level for 40 years by 2030 PV module degradation 0.4%/y
Minimize life-cycle environmental impact along the whole value chain of PV electricity generation, and increase recyclability of system components (in particular: of modules)	Recycling of kerf recovery of about 40% of pure silicon
	Recovery of polymers from PV module waste for chemical recycling >90% recovery of EVA, PVF, PVDF and PET
	End-of-Life recycling rate (EOL-RR) Silicon (90%), Indium (30%), Silver (70%), Cadmium/Tellurium (95%)
	Energy required to produce MGS < 20 kWh/kg (current value 32 kWh/kg)
	Primary raw material usage 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)
	Primary raw material usage for BOS i.e., concrete and steel Reduction by at least 3% (4% reduction by 2030 and further 6-7% by 2050)
	Carbon footprint PV tandem system < 40 g CO2-eq/kWh, thin film single junction < 20 g CO2-eq/kWh
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	Lifetime in Eco-design 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.
	% repair/reuse after EoL of first life PV >50% years of operation for reused modules >10 years cumulative lifetime minimum 40 years

The SRIA went then through targeted consultation with relevant experts and interest groups and will be published in April 2022.
The list of KPIs with the mapping with the existing activities of the Implementation Plan was sent to the IWG-PV and was subject of discussion with the IWG-PV Secretariat. The Chairs of the IWG-PV has since then decided to enter into a phase of adaptation of the Implementation Plan using a new setting based on the SRIA structure which will revolutionise the look of the Implan. The feedback phase from the members is still ongoing and the IWG-PV is foreseeing an update of the IP in the second half of 2022.

7. Contacts

Project coordinator

EUREC
Andrej Misech
Place du champs de Mars 2, B-1050
Brussels, Belgium
Email: andrej.misech@eurec.be
Phone: +32 2 318 4048

Work Package Leader

Eurac Research
David Moser
Viale Druso 1
39100 Bolzano
Italy
Email : david.moser@eurac.edu