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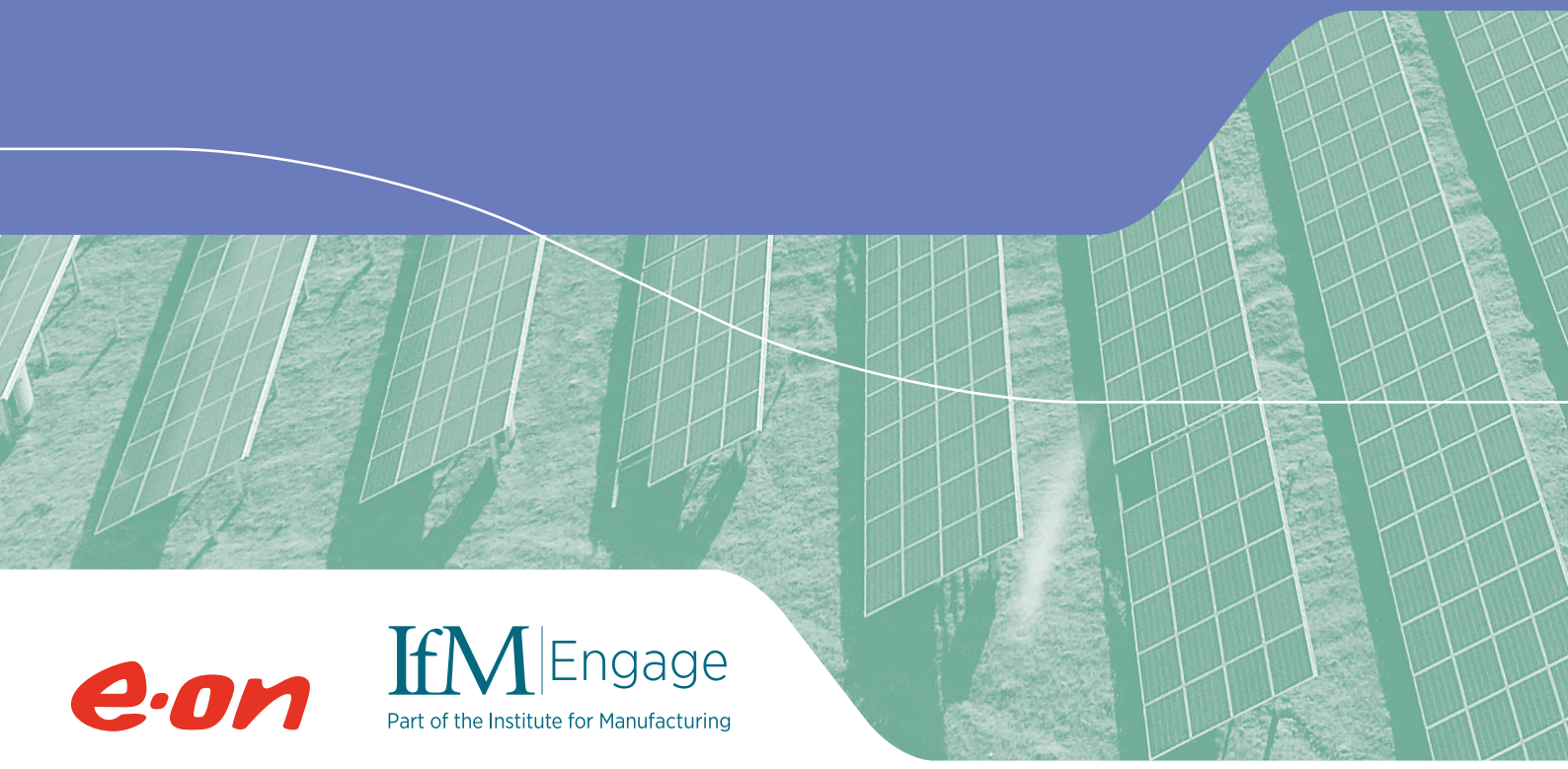
Circular Solar: The Opportunities and Challenges for Increased Circularity in the Solar PV Industry

Annex 2

Supplementary Information



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About this annex

This annex provides supplementary information to *Circular Solar: The Opportunities and Challenges for Increased Circularity in the Solar PV Industry*. The report is the final output of a collaborative, multi-disciplinary research project by the University of Cambridge Institute for Sustainability Leadership (CISL), IfM Engage at the University of Cambridge and E.ON Group Innovation GmbH. The year-long project, running throughout 2024, was funded by E.ON Group Innovation. It combined a background literature review with detailed technological analysis, insights from industry experts and policy analysis.

This annex includes information on recent and ongoing research projects funded through the EU's Horizon research programme (Annex 2.1) and policy instruments that could be deployed to enhance the supply and demand of circular economy strategies (Annex 2.2). The material included in this annex is referenced in the main report but excluded from the primary document due to space constraints. It offers additional details and examples to support and expand on the topics discussed in Chapters 4, 5, 6 and 7.

Annex 2.1 : Relevant EU research projects

Table A2.1: Horizon projects supporting knowledge development around circularity in the PV industry

Name of the H2020 project	Description	Period	Overall budget	Members
CABRISS	"Implementation of a circular economy based on recycled, reused and recovered indium, silicon and silver materials for photovoltaic and other applications."	June 2015 to May 2018	€9 million	16 partners from 8 countries: 6 small and medium-sized enterprises (SMEs), 5 industries, 5 research and technology organisations (RTO) Co-ordinated by CEA (French Alternative Energies and Atomic Energy Commission)
Eco-Solar	"40% eco-efficiency gains in the photovoltaic value chain with reduced resource and energy consumption by closed-loop systems" (reuse, recovery).	October 2015 to September 2018	€5 million	11 partners Co-ordinated by Syntef AS
ELSi	"Industrial-scale recovery and reuse of all materials from end-of-life silicon-based, photovoltaic modules."	May 2016 to April 2018	€3 million	Co-ordinated by Geltz Umwelttechnologie GmbH
CIRCUSOL	"Circular Business Models development and demonstration for the solar power industry", with a focus on service-based ones (Product-Service System – PSS).	June 2018 to May 2022	€8 million	15 partners from 8 countries: 5 research centres and universities, 9 industrial players from the PV and battery value chains, 1 consultancy firm Co-ordinated by VITO (Flemish Institute for Technological Research)
PVadapt	"Prefabrication, Recyclability and Modularity for cost reductions in Smart BIPV systems" (design for recyclability).	October 2018 to March 2022	€11 million	18 partners Co-ordinated by Merit Consulting House sprl
HighLite	"High-performance low-cost modules with excellent environmental profiles for a competitive EU PV manufacturing industry" (ecodesign).	October 2019 to September 2022	€15 million	18 partners Co-ordinated by Interuniversitair Micro-Electronica Centrum
PRO-S	"The first highly energy-efficient and eco-friendly bio based-photovoltaic module that works without sunlight or battery consumption for Smart buildings" (toxic-free and recyclable – ecodesign).	December 2019 to April 2020	€71 thousand	Co-ordinated by Proton New Energy Future SL

Name of the H2020 project	Description	Period	Overall budget	Members
Trust-PV	"Increase Friendly Integration of Reliable PV plants considering different market segments" (reduction of failures, increase recyclability).	September 2020 to August 2024	€12 million	20 partners Co-ordinated by Accademia Europea di Bolzano
BOOSTER	"Organic photovoltaics for eco-friendly buildings" (non-toxic resources – ecodesign).	September 2020 to August 2024	€8 million	Co-ordinated by Armor AS
Ramp-PV	"Raw material up-cycling for circular PV" (recycling).	November 2020 to October 2022	€1 million	Co-ordinated by the French company Rosi Solar
PHOTORAMA	"To develop trailblazing technologies to implement a strong and reliable PV recycling scheme To demonstrate full circularity by re-injecting the secondary rare materials into cross sectoral value chains To drive market adoption of PHOTORAMA technologies as sustainable solutions To strengthen sustainable waste management actions under the European Innovation Partnership (EIP) framework."	2021 to 2025	€8.38 million €	13 organisations active in the PV value chain, from Austria, Belgium, France and Germany to Italy, Norway and Spain
EVERPV	"...develop sustainable solutions for handling end-of-life solar panels in the EU."	September 2023 to August 2026		16 partners from the entire solar industry value chain, including solar panel production, end-of-life solar PV panel collection and solar panel waste treatment
RESiLEX	"RESiLEX will impact on the whole Silicon value chain: starting from developing more efficient photovoltaic solar cells and modules, up to implementing a new circular model, where end-of-life solar panels are recycled and reused."	June 2022 to May 2026		
QUASAR	"Develop and implement solutions for systematic collection and management of end-of-life PV-modules, integrating various technologies and methodologies."	February 2024 to January 2027		QUASAR brings together a multidisciplinary consortium involving 19 industrial players from the entire photovoltaic supply chain: photovoltaic module manufacturers, photovoltaic system operators, collectors, recyclers and end-users of secondary raw materials

Compiled by authors with information from "Moving towards a circular photovoltaic economy in Europe" (Ariolli 2021). Accessed December 30, 2024, https://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=9061653&fileOId=9061654. Operational dates and budgetary numbers are approximate.

Annex 2.2: Detailed policy recommendations

This annex provides more detailed examples of various policy measures that could promote greater circularity within the solar PV value chain, relating to Chapter 7 of the main report.

Table A2.2 seeks to provide a 'menu' of policy instruments from which the most suitable ones could be deployed at any one time, bearing in mind that they apply to various levels of governance (national, EU) and are likely to be subject to varying degrees of public support or opposition (which may vary depending on the Member State context). These examples were developed based on the literature review and qualitative evidence collected during this project. They are organised into 'types' of actions (rows) to address the key barriers discussed in Chapter 6 of the report (columns).

It is important to note that policy instruments are highly context dependent; a measure that is successful in one setting may fail in another. Policies may also have unintended consequences, which could either enhance or undermine their effectiveness or interfere with the success of other, unrelated policies. Before implementing any policies, it is therefore advisable to carry out a thorough impact assessment and analysis to identify and address any potential adverse effects.[1]

It is also worth noting that a single policy measure is unlikely to produce significant results on its own. Desired outcomes are typically achieved more effectively through a combination of policy measures and government actions.[2]

Table A2.2: Policy measures and government actions to support increased circularity in the solar PV value chain

	Technology development and entrepreneurial activities (incl. new business models)	Market formation and legitimisation	Resource mobilisation and development of positive externalities
Legal and regulatory measures	Reclassify decommissioned solar PVs as sources of reusable components and materials rather than 'waste' (to allow whole PVs and components to be moved from one Member State into another for processing when necessary to enable economies of scale to develop faster). Establish regulatory sandboxes to test new ideas/materials in a controlled environment to assess their suitability. The results from regulatory sandboxes can be used to inform technology and product standards relating to solar PV design, disassembly, recycling and decontamination of materials.	Mandate, through the enforcement of the Ecodesign Directive, sustainable product design standards for solar PVs. Supplement the Ecodesign Directive with an obligatory environmental product declaration for PV panels. Over time, these could be expanded to include minimum standards on embodied carbon content of all materials and components, or recycled material content requirements. Introduce clear emissions accounting and reporting protocols and standards, including a monitoring framework and a digital platform that enables data to be shared across the value chain.	Collaborate across the EU to identify suitable locations and business models for centralised or collaborative services for processing specific parts or materials from decommissioned solar PVs. The operation of disassembly and recycling services in a way that allows economies of scale to develop for specialised services must be supported by revision of EU-wide regulations on transporting 'waste', or reclassification of decommissioned PVs as a reusable good rather than waste. At the early stages, when volumes are not yet large enough to enable collections and specialised recycling services to be financially viable, these could be funded through subsidies from levies imposed on 'producers' (as defined in clarification of the WEEE).

	Technology development and entrepreneurial activities (incl. new business models)	Market formation and legitimisation	Resource mobilisation and development of positive externalities
Legal and regulatory measures *(continued)*		Establish mandatory minimum recovery rates for high-value materials (eg silver, PV-grade silicon etc) at certain purity levels to encourage the deployment of high-value material recovery and recycling technologies. Mandate recycling of PVs for all owners of PVs, including private households and commercial users (such as supermarkets and SMEs). An EU-wide ban on landfilling of solar PVs to create more demand for recovery, reuse and recycling services. Phase in a ban on solar PV imports that do not meet the ecodesign requirements for solar PVs (as these become enforceable in the EU) to incentivise more circular design among foreign and domestic manufacturers.	
Financial and fiscal measures	Fiscal incentives for companies (both established and start-ups) to invest in new product designs to make solar PVs easier to repair, disassemble and recycle. This should include experimental new technologies and new business models for circularity across the PV value chain, and expansion of company activities to aid the transition to a more circular economy (including quality testing operations for reusable components and products). Business rate deductions or exemptions to corporates that invest a certain share of profit into R&D to enhance PV circularity (apply to companies across the value chain). Fiscal incentives to encourage solar PV as a service model, with circularity requirements imposed on owners.	Phase in additional tariffs on solar PV imports that do not meet the ecodesign requirements for solar PVs (as these become enforceable in the EU) to incentivise more circular design among foreign and domestic manufacturers AND/OR remove all tariffs from solar PVs that are easy to disassemble and recycle, and come with recycling instructions (tariffs are an alternative to a total ban). Tax deductions/exemptions for solar PV retailers/leasing companies that commit to circular practices that exceed the minimum required by law/regulation. Tax deductions, subsidies, grants and subsidised loans that cover a considerable share of the capital cost of investing in newly emerging experimental technologies as soon as they reach the market, but incur a cost premium (eg deployment of transformational technology). Reductions or exemptions on VAT on repair services (including refurbishment and repowering) and replacement parts.	Encourage repairs and the reuse of second-life solar among all consumers (including households and businesses) through subsidies and fiscal incentives. Certain tax exemptions already exist in Germany on certain types of solar PV system. These could be expanded to other types/user groups and applied across other EU countries.

	Technology development and entrepreneurial activities (incl. new business models)	Market formation and legitimisation	Resource mobilisation and development of positive externalities
Risk sharing and risk mitigation mechanisms	Government-backed insurance schemes for companies setting up operations around solar PV disassembly, material recovery, material decontamination and recycling, as well as businesses that specialise in testing, repairing and re-selling second-life solar PVs and reusable components.	Government-backed insurance schemes for companies using repaired (second-life) PVs, PV components or materials in their products. Require solar PV manufacturers and retailers to extend valid warranty of products if a part is replaced by a qualified repairperson.	
Public sector investment	Direct EU funding to R&D and seed funding for companies exploring and piloting 'higher R' strategies (such as reuse, repair and remanufacturing) alongside recycling. Direct public funding to develop mechanisms to emerging digital technologies and AI to identify where solar PVs are, in what quantities and of what age. Collaborate with companies and consumers to register and track all PVs in Europe.	Allocate government contracts to first movers/adopters/ users of new circular practices, technologies and services.	Allocation of government funding to support convening activities and funding programmes by non-departmental government bodies to support knowledge generation and collaboration between academic institutions and the private sector to facilitate the emergence of new insights, best practices and innovative solutions. Direct public sector funding from Member State and EU budgets to infrastructure and awareness-raising campaigns
EU-level and international collaboration	Produce open access market data/studies to help estimate the waste streams to better identify business opportunities and to assess the financial viability of new technologies and services.	Collaborate with major trade partners to implement requirements for PV lifecycle emissions and sustainable design. Collaborate with trade partners and other major economies to develop and implement a shared framework for reliable, standardised and comparable data on whole lifecycle emissions and recyclability of solar PVs. Direct public sector funding to support global initiatives that are led by the private sector and non-governmental organisations on sustainable design of solar PVs and technologies supporting more circular practices across the PV value chain (similar model to SteelZero and ConcreteZero).	Develop EU-wide accreditation schemes for solar PV repairers, and set up an EU register of appropriately accredited people. Invest EU funds in disassembly and recycling infrastructure, new technologies, innovation and facilities spread strategically across the EU countries to create economies of scale instead of requiring each country to set up their own facilities (pan-European circular solar project). Align the definition of 'producer' in the WEEE rules across the EU to avoid inconsistencies in enforcement at Member State level.

References

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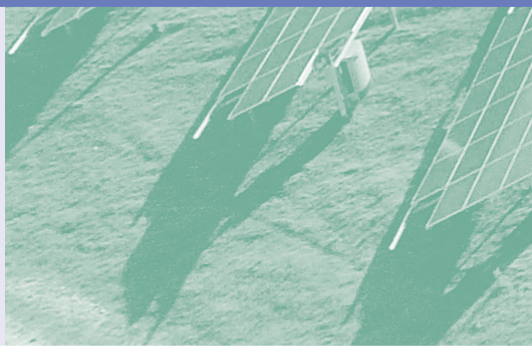

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