ESIA European Solar PV Industry Alliance

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EUROPEAN SOLAR INDUSTRY ALLIANCE

RECOMMENDATION PAPER SERIES IX

Recyclability and Sustainability Criteria for Ecodesign Regulation (2009/125/Ec) of Photovoltaic Modules

Background

The European Green Deal, reinforced by the Competitiveness Compass, highlights the critical role of Europe's industries in reducing both carbon and material footprint, while embedding circularity across the economy.1 It calls for a departure from traditional models and a transformation in how we design, produce, use, and dispose of products, alongside ensuring a secure supply of raw materials. The Ecodesign regulation for photovoltaic (PV) modules aims to achieve precisely that by establishing specific requirements for carbon footprint, information disclosure, design for reliability and recyclability.2 These objectives aim to reduce the overall environmental and climate impact of PV modules across their entire lifecycle, including the recovery of critical and strategic raw materials, minimizing waste, and establishing sustainability performance benchmarks across the industry. These measures also contribute to strengthening the EU's resilience in supply chains and resource management of energy-related products. While the Ecodesign Directive 2009/125/EC has been repealed and replaced by the Ecodesign for Sustainable Products Regulation 2024/1781 (ESPR) for many products, photovoltaic panels remain one of the exceptions from ESPR until the end of 2026. This is to avoid losing the preparatory work, which is at a substantially advanced stage for PV modules. Restarting it under ESPR would considerably delay the adoption of Ecodesign requirements for PV modules.3

To support the European Commission with a fast implementation of the Ecodesign regulation for PV modules, the European Solar PV Industry Alliance (ESIA) has developed a list of recommendations. The recommendations put forward are essential for fostering comparability, ensuring harmonized implementation, and maintaining technological neutrality in the criteria established by the Ecodesign regulation.

Recyclability and Sustainability Criteria for PV modules

To ensure that the European Union has secure and sustainable access to the net-zero technologies essential for its resilience and climate neutrality goals, it must foster an environment supportive of innovation in this sector. As highlighted in the Solar Charter, innovation is vital not only for achieving the Union's net-zero objectives but also for maintaining its global competitiveness.[4] In contrast, the Ecodesign regulation only applies to current PV technologies and does not include future PV technologies, such as perovskites and other innovative thin films, as well as tandems beyond a perovskite-silicon combination. Sidelining innovative technologies risks stifling the breakthroughs necessary for future advancements. To close the gap in innovation, policies must be designed to be inclusive of all such *key enabling technologies*, so that potential integrations of those policies with public procurement and auctions does not disrupt the development of next-generation technology across member states. **Therefore, the ESIA recommends a technology neutral approach for Ecodesign regulation which welcomes all technologies to the market that ensures the reliability requirements.** This inclusiveness can be observed in the Product Environmental Footprint Category Rules (PEFCR) for PV system [5] and the Net-Zero Industry Act Implementation Act.[6]

As for the Ecodesign criteria, the working document[2] lays down guidelines for *carbon footprint*, *information disclosure*, *design for reliability* and *material circular footprint formula (CFF)* while the development of the *recyclability index* is still on-going. Although the *carbon footprint* should remain the key component of Ecodesign regulation, it is tackled in the recommended Series VII[7], and therefore, not further discussed in this paper.

For the criterion on *information disclosure*, the Ecodesign has set the following eleven requirements to be provided in the form of a user manual on a free access website of the manufacturer, importer or authorised representative:

- ***a)*** *manufacturer's name, registered trade name and registered trade address at which they can be contacted;*
- ***b)*** *product model number;*
- ***c)*** *year of manufacture;*
- ***d)*** *the Energy Efficiency Index (EEI_M) under 'temperate coastal', 'temperate continental' and 'subtropical arid' climate conditions, expressed in kWh/m^2 and rounded to the unit;*
- ***e)*** *lifetime performance degradation rate, expressed in % and rounded to the second decimal place;*
- ***f)*** *information on how to access and replace the bypass diodes in the junction box;*
- ***g)*** *information on how to replace the whole junction box of the module;*

h) *information on how to separate and recover the semiconductor from the frame, glass, encapsulants and backsheet;*

i) *information on the feasibility of clean separation without breakage of the glass, contacts and internal layers during the dismantling operations at the end of life shall be detailed.*

j) *results of the test on the capability to withstand prolonged exposure in open-air climates;*

k) *indicative weight range of the following critical raw materials and environmentally relevant materials*

First, **the ESIA supports the Commission's drive towards transparency in information, however, it is recommended to categorize the information based on their sensitivity and associated risks.** While some information (a-c, e and f) are less sensitive, the requirements (g-j), such as on end-of-life management, are too detailed for customers and often contains proprietary information which is critical for a competitive edge. In addition, manufacturers often have agreements with customers or partners that include strict data confidentiality clauses, limiting the sharing of sensitive information. For this reason, the information requirement for public disclosure must balance the need for transparency with the imperative to protect core intellectual property of the manufacturers. As a solution, this regulation should continue to promote disclosure of the product identifying information (a-c, e and f), while for the sensitive information (g-j), only require a disclosure that such information is available under confidentiality agreement with utilities and end-of-life managers.

Second, **the ESIA recommends a sensible approach on the information requirement on the Energy Efficiency Index (d).** Since that information is planned to be communicated through the PV Energy Label, any unnecessary redundancy in information requirements should be avoided, effectively reducing calculation and verification burdens, and ensuring optimal complementarity between the Ecodesign requirement and the Energy Label requirement. Furthermore, the challenges with the kilowatt-hour per square meter (kWh/m^2) per year approach in representing the overall energy performance of the modules are elaborated in ESIA Recommendation Series VII.[7]

Third, for the material disclosure requirements (k), **the ESIA recommends a wider selection of materials than what is laid forward by the regulation, to be disclosed above certain thresholds.** PV innovation often requires new material combinations, and limiting these options risks the energy transition. Instead, all valuable, critical, and environmentally sensitive materials must be managed through strong end-of-life management practices, focusing on greater material recovery and circularity.

While the increasing volume of PV panel waste poses environmental challenges, it also presents opportunities to create value and explore new economic paths through recycling. A 2016 EU JRC report identified one of the main barriers to PV recycling as the lack of awareness among recycling operators about the materials used in PV modules[9] and the Ecodesign framework aims to close this gap of information.

Information on the following categories of materials are of key interest, most of which has been captured already by the existing draft of the regulation:

i. **Recycling Disruptors:** The EU JRC has emphasized the importance of clear labelling on products that contain materials which disrupt recycling processes.[9]

- **Halogen content:** The presence of halogens (e.g., fluorine) complicates recycling, since PV modules with halogenated plastics require specialized incineration plants for processing.
- **Antimony content:** Solar glass containing antimony requires specialized treatment.

ii. **Critical Raw Materials (CRM) and Strategic Raw Materials (SRM):** According to the European Commission, materials are considered critical when their economic importance and supply risks exceed thresholds set by the Commission.[10] Rather than selecting some CRMs and leaving out others, it is recommended to refer to all the CRMs and SRMs identified by European Commission's official list in 2023 below, which includes further PV relevant materials, such as Bismuth.

CRM and SRM as identified by the Joint Research Centre of the European Commission:

2023 Critical Raw Materials (*new CRMs in italics*)			
aluminium/bauxite	coking coal	lithium	phosphorus
antimony	*feldspar*	LREE	scandium
arsenic	fluorspar	magnesium	silicon metal
baryte	gallium	*manganese*	strontium
beryllium	germanium	natural graphite	tantalum
bismuth	hafnium	niobium	titanium metal
boron/borate	*helium*	PGM	tungsten
cobalt	HREE	phosphate rock	vanadium
		*copper**	*nickel**

2023 Critical Raw Materials (*Strategic Raw Materials in italics*)			
aluminium/bauxite	coking coal	*lithium*	phosphorus
antimony	feldspar	*LREE*	scandium
arsenic	fluorspar	*magnesium*	*silicon metal*
baryte	*gallium*	*manganese*	strontium
beryllium	*germanium*	*natural graphite*	tantalum
bismuth	hafnium	niobium	*titanium metal*
boron/borate	helium	*PGM*	*tungsten*
cobalt	*HREE*	phosphate rock	vanadium
		*copper**	*nickel**

* Copper and nickel do not meet the CRM thresholds, but are included as Strategic Raw Materials.

iii. **Scarce and Precious Materials:**

- **Silver:** In crystalline silicon based PV technology, silver is used for module metallization. There is significant economic interest in recovering silver.
- **Tellurium and Indium:** Utilized in thin film technologies and transparent conducting oxides.

iv. **Environmentally Sensitive Materials:** Lead metal, cadmium and selenium are commonly used in the PV industry.

Advanced (high-value) recycling processes help recover scarce, precious, and environmentally sensitive materials.

Fourth, as information will be disclosed on a website (i.e. without space limitation), **the ESIA recommends disclosure of all material beyond a 0.1% weight by weight.** This approach of disclosure of the inventory of material composition above a 0.1% weight-by-weight threshold is observed in the Norwegian Environmental Product Declaration (EPD) System[11] and the guidance of the EU Battery Passport by the Battery Pass consortium.[12] The advantages of the *percentage weight-by-weight disclosure* approach is that:

- It provides useful information to end-of-life managers, while the threshold protects proprietary information.
- It enhances comparability between products. For instance, it is simple to compare between module A with 2% Ag versus module B with 3% Ag content. This approach is well-aligned as the Ecodesign also prioritizes to *'inform users in a comparable manner … to provide them with a common basis to compare different products before making their purchase.'* [2]

On the other hand, as observed in the Ecodesign working document,[2] a different approach has been considered where selected materials are disclosed in ranges- such as 'less than 2 g', 'between 2 g and 20 g' and 'above 20 g'. The challenge with this type of *bracketed range in grams disclosure* approach is that:

- It does not give end-of-life managers necessary information to allow recycling at scale.
- It has reduced comparability due to the wide disclosure ranges and varying sizes of solar modules.
- With the current trend of increasing wafer sizes, larger modules will have to report higher weight brackets while smaller modules will inherently report the smaller weight brackets.

Fifth, the Ecodesign rightfully sets 11 reliability criteria that are key to ensuring a module is market entry worthy. One of those criteria is *the long-term reliability of the bypass diodes* (xi). For this particular criterion, **the ESIA recommends ensuring the overall long-term reliability of the PV modules in accordance to the EN IEC 61215:2021 series rather than focusing only on bypass diodes.** The overall long-term reliability of the PV modules is sought after by customers and developers as a key performance indicator.

Lastly, the Ecodesign promotes the Circular Footprint Formula (CFF)[13] for modelling recycled content and materials recycling, which is the Commission's harmonized approach for all products environmental footprint guidelines. This comprehensive formula takes into account different parameters including the recycled content as well as the quality of the recyclate, promoting high value recycling. High-value recycling is important for all PV technologies to maximize the recovery of the most valuable fractions.

The ESIA cautions in the use of recycled content claims in the CFF and recommends the validation of such claims in accordance with for instance, UL 2809 standard, the global EPEAT Ecolabel for Solar,[14] or the Norwegian Environmental Product Declaration (EPD) System[11], or equivalent credible verification system. It must be ensured that the notified bodies authorized to verify such claims have PV specific knowledge to protect the integrity of the recycled content. Disclosure of verified recycled content claims should be encouraged.

In general, collaboration among stakeholders—including suppliers, recyclers, manufacturers and policymakers—is essential to align sustainability and recyclability requirements with circular economy goals. Public disclosure of recycling rates and secondary raw material integration can be encouraged in further revisions. By adopting the above stated best practices, the European Commission can set robust and globally aligned criteria for photovoltaic products, ensuring a transition to a circular and sustainable solar industry.

Future Work

Looking ahead, the ESIA has outlined the following long-term goals to ensure the sustainability and recyclability of solar products.

PV Recyclability Index: As the PV Recyclability Index may play a crucial role in the Ecodesign regulation as a recyclability criterion, this task force will closely monitor its development and provide feedback as needed to enhance its effectiveness.

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