EXPERT INPUT PAPER – ECO-DESIGN & ENERGY LABELLING FOR PHOTOVOLTAIC MODULES, INVERTERS AND SYSTEMS IN THE EU

ETIP PV, SolarPower Europe, PVthin, European Solar Manufacturing Council, IECRE

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The recommendations presented in the Expert Input Paper are the result of a Joint Mission Group of Solar Industry Experts and Researchers, building on the findings of the European Commission Preparatory Study for Eco-Design, Energy Labelling, Green Public Procurement and Ecolabelling. The findings of the Expert Input Paper aim to support the criteria development process within the framework of compulsory policy instruments further evaluated in the supporting study.

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Disclaimer

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INTRODUCTION

As stated in the EU Green Deal Communication[1], the just transition to climate neutrality and a sustainable future is the overarching objective of all EU policies and actions. The decarbonisation of the energy sector, investments into environmentally friendly technologies and helping industry innovate are essential elements of this transition. The proposed European Climate Law[2] and the Green Deal Key Actions[3] build on the Clean Energy Package's Renewable Energy Directive (RED II)[4] targets for the mass deployment of solar, wind, hydro and other forms of sustainable energy conversion technologies. Solar photovoltaics could play the leading role in this transition: it is quickly becoming the most economic form of electricity generation worldwide, and consequently the IEA has declared PV to be the "new king of electricity" in its World Energy Outlook 2020[5]. The pathway to terawatts of solar being deployed required a number of dedicated policy and standardisation activities to ensure that the photovoltaic (PV) value chain is growing in a manner which is resource efficient, environmentally safe and protective of human health. The PV industry today is working effectively towards decoupling economic growth from negative environmental impacts and resource consumption.

Over the last five years, the PV industry has pro-actively engaged with regulators, policy makers and wider stakeholder groups, to quantify the environmental performance of PV technologies and demonstrate the tangible advantages of the different PV technologies available. In the EU, the PV industry participated in the Product Environmental Footprint (PEF) Pilot Phase[6], and developed sectoral Product Environmental Footprint Category Rules (PEFCR) for Photovoltaic Modules used in photovoltaic power systems for electricity generation[7]. This validated the environmental performance of PV technologies in the EU, and helped better inform decisions on what EU sustainable product policies would be most appropriate for this category of products. The PEF pilot phase, the development of the PEFCR as well as the related pilot and screening studies, clearly identified the environmental hotspots in the life cycle of PV systems, aiding in the development of voluntary industry standards to address these hotspots at a global level[8,9].

Building on the results of the PEF pilot phase, the European Commission added photovoltaic panels and inverters to the work program for Eco-Design in 2016[10] and extended the Preparatory Study[11] carried out from 2017 to 2019 to also assess whether sustainable product policy instruments such as the EU Energy Label, Ecolabel and Green Public Procurement would be appropriate for the PV industry.

1 *Communication from the Commission: The European Green Deal; COM(2019) 640 final*
2 *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law); COM(2020) 80 final*
3 *Annex to the Communication on the European Green Deal Roadmap - Key actions; COM(2019) 640 final*
4 *DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)*
5 *IEA World Energy Outlook 2020, https://www.iea.org/reports/world-energy-outlook-2020*
6 *Product Environmental Footprint (PEF) Pilot Phase, https://ec.europa.eu/environment/eussd/smgp/ef_pilots.htm*
7 *PEFCR PV electricity v. 1.1; https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_PV_electricity_v1.1.pdf*
8 *Wade, Andreas, Philippe Stolz, Rolf Frischknecht, Garvin Heath, und Parikhit Sinha. „The Product Environmental Footprint (PEF) of photovoltaic modules-Lessons learned from the environmental footprint pilot phase on the way to a single market for green products in the European Union". Progress in Photovoltaics: Research and Applications, 2017. https://doi.org/10.1002/pip.2956.*
9 *Wade, Andreas, Parikhit Sinha, Karen Drozdiak, Dustin Mulvaney, und Jessica Slomka. „Ecodesign, Ecolabelling and Green Procurement Policies – enabling more Sustainable Photovoltaics?" In WCPEC-7, Proceedings of the 7th World Conference on Photovoltaic Energy Conversion. Hawaii, USA: IEEE, 2018.*
10 *Ecodesign Working Plan 2016 – 2019, COM(2016) 773 final*
11 *JRC, Solar Photovoltaic modules, inverters and systems preparatory study; https://susproc.jrc.ec.europa.eu/solar_photovoltaics/*

The Commission's policy scenario evaluation concluded that the best way to further regulate PV panels was via a combination of mandatory and voluntary policy instruments. This scenario evaluation considered mandatory instruments such as Eco-Design measures for photovoltaic panels and inverters, augmented by the use of the Energy Label for residential PV systems, and voluntary instruments such as Green Public Procurement Criteria. The latter aspects will be developed between 2020 and 2023 to focus on a number of sustainability, quality, durability, circularity and performance criteria[12].

In order to inform the development of these criteria, representatives of the photovoltaic value chain came together to set up a Joint Mission Group under the umbrella of the European Technology Innovation Platform Photovoltaics (ETIP PV)- in cooperation with SolarPower Europe, PVThin, the European Solar Manufacturing Council, and IECRE - to review the results of the preparatory study and provide recommendations for the next regulatory discussions.

As outlined below (Fig. 1), between June 2020 and January 2021, the Joint Mission Group (JMG) followed a structured approach to provide a comprehensive review and set of recommendations to support the discussions on the compulsory policy instruments of Eco-Design and the Energy Label – complemented by a dedicated investigation of the cross-cutting and more general sustainability criteria.

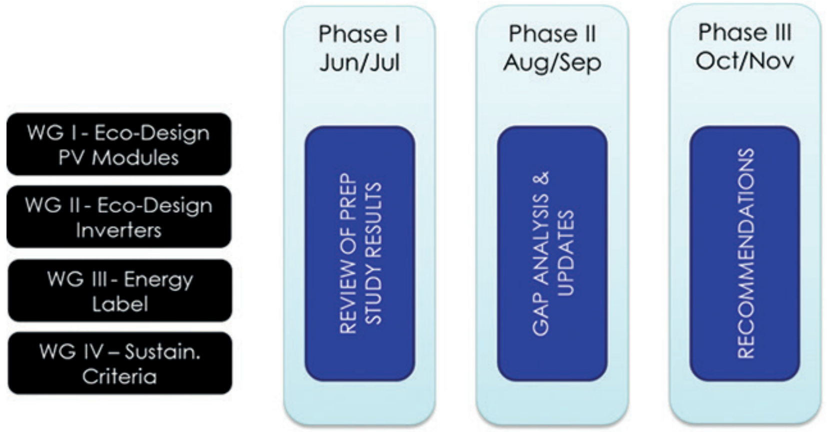


Figure 1: Joint Mission Group approach (2019)

The Expert Input Paper aims to comment on the recommendations of the policy recommendations set out in the Final report[13] and extend those to reflect on identified gaps and required updates from the perspective of the solar industry & solar research community.

The first part of the report is structured as direct feedback to the policy recommendations. The second part of the report provides additional recommendations from the expert group to achieve the policy objectives.

A final comment in the introduction is to recommend periodic reviews of the directives every 2 years.

12 *Preparatory study for solar photovoltaic modules, inverters and systems – Final report; Dodd, N., Espinosa, N., Van Tichelen, P., Soares, A., JRC B.5 unit, VITO, 2020*

13 *Ibid.*

SUMMARY OF RECOMMENDATIONS FOR POLICY MAKERS

Photovoltaics is a proven technology capable of making a substantial contribution to a sustainable global energy system. Its widespread use in all geographic regions, versatility in application, modularity in scale enables a socially acceptable energy transition by offering distributed electricity generation, employment and new business opportunities.[14]

The Joint Mission Group welcomes the policy recommendation on the introduction of eco-design requirements for photovoltaic modules and inverters in the EU. These future requirements should be based on standards, which determine the service life, energy yield and degradation – which are the most important parameters influencing the sustainable performance of these components. Given the longevity of the components and the fast evolution of new products & technology concepts, reference values established through accelerated life cycle testing and lifetime yield prediction should provide minimum requirements for performance guarantees, replacement and reparability within the eco-design regulations.

The introduction of an Energy Label for residential scale photovoltaic systems will be a novelty for electricity generating equipment and runs a risk of confusing and disincentivising the electricity prosumer. In line with the policy priorities of all supporting organizations, the Joint Mission Group wants to re-emphasise that every kilowatt peak of solar electricity generation capacity installed provides significant environmental and societal benefits in achieving the green transition of the EU Economy. Given the available, enormous potential of private and commercial rooftops and facades across the European Union to become active generators and empower electricity prosumers, an Energy Label should not disincentivise development of specific applications, but rather ensure transparency of environmental and quality performance of the system components deployed to allow conscious and informed choices.

An informed electricity prosumer in the European Union should have comprehensive and holistic sustainability performance data available for the photovoltaic modules and inverters upon purchasing those components. The lifecycle environmental impact of these system components is well understood, and lifecycle hotspots have been identified and can be effectively addressed by creating market pull for more sustainable products. The introduction of an independently validated combined Energy & Environmental Impact Index, embedded in a quality conformity assurance framework is seen as the most effective mean to enable this transparency and induce the continuous improvement in sustainability performance of these product groups.

The introduction of product sustainability regulations should also support long-term energy security, resource resilience and the revitalisation of all of the value chain of PV products in the EU.

14 *See also: Photovoltaic Solar Energy: Big and Beyond – Sustainable Energy to Limit Global Warming to 1.5 Degrees – Vision and Claims of the European Technology and Innvation Platform for Photovoltaics (ETIP PV), 2020*

PART 1: FEEDBACK ON POLICY RECOMMENDATIONS

The direct feedback on the policy recommendations results from the phase I review and phase II gap analysis of the preparatory study reports. The feedback is structured per requirement proposal taken from the task 8 report[15] and summarised in the respective ***Joint Mission Group (JMG) tables***.

Additional references and recommendations for the supporting study and the regulatory proposal are provided, if needed, in the Annex to this document (as done for the benchmarking calculation on the proposed Energy Efficiency Index for residential scale systems).

Recommendation 1: Ecodesign requirements for modules and inverters

Exclusions

The task 8 report recommends the introduction of requirements that would apply to individual modules and inverter products placed on the EU market and intended for use in photovoltaic systems for grid-connected electricity generation. Specific exclusions from the scope would be:

For modules	For inverters
• Module level power electronics, containing micro-inverters and power optimizers • Modules with a DC output power of less than 50 Watts under STC • BIPV products • Modules intended for mobile applications or integration into consumer electronic products	• Central inverters that are packaged with transformers as defined in Commission Regulation No 548/2014 (…)

JMG Feedback

Issue	Recommendations & References
Modelling / Comparison of inverters, module-level inverters and hybrid inverters not possible.	The proposed supporting studies should be adapted so that modelling of module-level inverters and hybrid inverters (inverters with attached storage system) is possible and to ensure consistencies in analyses and interpretations.
Currently, focus only on modules and inverters, currently neither balance-of-system (BOS) components, nor battery systems included in the policy evaluation.	Consider the inclusion of relevant BOS components and storage (particularly battery, expected to be more and more implemented in the coming years) systems in the overall sustainability assessment. Set up an expert team to come up with proposal; possibly triggered by IECRE stakeholder group SG452 or SG453 (both established 9/2020)
Regulation (EcoDesign Regulation EU 548/2014) excludes medium voltage Inverters up to 5 MVA, which is the typical size for central inverters.	Exclude only central inverters shipped with medium voltage transformer

15 Dodd, Nicholas; Espinosa, Nieves – JRC B5; Preparatory study for solar photovoltaic modules, inverters and systems, (Draft) Task 8 Report: Policy recommendations; December 2019

PART 1: FEEDBACK ON POLICY RECOMMENDATIONS

Requirements on lifetime electricity yield for PV Modules

The task 8 report recommends the introduction of a declaration requirement for the module yield calculated according to IEC 61853 part 3 with reference to the climatic zones in part 4.

Performance aspect	Detailed proposed requirements
Module energy yield	The module energy output (yield) expressed in kWh/kWp and calculated according to IEC 61853-3 for each of the three reference EU climate zones shall be declared by the manufacturer.

JMG Feedback

Issue	Recommendations & References
IEC 61853-3 calculates the initial annual energy yield considering non-STC effects. To calculate the energy yield the module produces over its lifetime the degradation and lifetime should also be considered. The application of IEC 61853-4 to define the reference climates for the calculation of the energy yield for the reference systems should be reconsidered, as the respective climate zones / latitudes provided are un-representative of the EU country latitudes – as the difference between data set 3 (Sahara latitude) and data set 4 (Northern Denmark latitude) shows- the missing granularity would lead to strong mischaracterizations of the energy yield within the EU.	Define reference locations within the EU for the annual energy yield calculation according to IEC 61853 to provide greater granularity and better performance characterization.
In "Transitional Methods" a lifetime of 30 years is given for all module technologies. This could be used to calculate the lifetime electricity yield; however, it does not reflect technological differences.	The module lifetime of the manufacturer's performance warranty (replacement, repair or refund) should be used. Important: Define minimum warranty requirements a manufacturer has to fulfil as part of the Eco Design requirement.
In "Transitional Methods" a prescribed degradation value of 0.7%/a and 1.0%/a is given for c-Si and for thin-film or c-Si/HJT, respectively. The latter is in strong contradiction to warranties of HJT modules currently offered. Technological differences such as glass-glass versus glass-backsheet are not considered. As an alternative validated field measurements are accepted. This is not transferable from site to site, technologies at different locations cannot be compared with each other and it simply takes too long.	The module degradation of the performance warranty of the manufacturer (replacement, repair or refund) should be used. Define minimum warranty requirements a manufacturer has to fulfil as part of the Eco Design requirement. Calculate the electricity yield over the lifetime considering the degradation using the IEC 61853 procedure for typical state-of-the-art modules to define the threshold value. Furthermore, the yield calculation methodology has to take into account transient effects of power stabilization in PV modules, such as light induced degradation (LID) and hence should require the application of stabilization tests prior power measurements used for yield calculations according to IEC 61853. Define lifetime energy yield classes to be used for energy labelling. Energy output in kWh/kW$_p$ only reflects one part of the efficiency, it is better to use kWh/m². The proposed "double normalization" to installed peak power and area would diminish system configuration differences as evaluated in the energy yield benchmark calculations provided in the Annex.
Bifaciality is not considered in IEC 61853-3, but it can have a very significant contribution.	Include bifaciality into the yield calculation model.

Performance requirements on quality, durability and circularity for PV modules

The task 8 report recommends the introduction of a more stringent set of quality and durability tests for module products.

Performance aspect	Recommendations & References
	Performance requirements
Durability product test sequence	Each model shall be certified to have passed the product test sequence required for qualification under IEC 61215. *This requirement could be further extended to require factory quality controls and auditing according to IEC TS 62941 and IECRE OD 405.*
	Information requirements
Lifetime performance degradation	The manufacturer shall declare the average linear degradation rate expected over a notional service lifetime of 30 years. This shall be the same rate that is used as the basis for the power warranty (if offered). The declaration shall be clearly identified as being either: • Validated: The manufacturer's claim shall be an average derived from a series of field observations made according to the Transitional Method, in regard to the number, geographical coverage and the time series. • Unvalidated: The manufacturer shall report on the basis for their claimed rate with reference to accelerate life testing methods and modelling.
Repairability	The manufacturer shall report on: • the possibility of access to and replace of the bypass diodes in the junction box, • the possibility of replacing the whole junction box of the module *Note: the possibility exists to include semi-quantitative criterion if a product specific standard is developed in accordance with the forthcoming horizontal standard for reparability prEN 45554.*
Dismantlability	The manufacturers shall report on the potential to separate and recover the semiconductor, resp. the cells (including contact metals) from the frame, glass, encapsulants and backsheet. Design measures to prevent breakage and enable a clean separation of the glass, contacts, resp. interconnections and internal layers during the operations shall be detailed. *Note: the possibility exists to include semi-quantitative criterion if a product specific standard is developed in accordance with the forthcoming horizontal standard for recyclability prEN 45555.*
Material disclosure	The manufacturer shall declare the content in grams of the following materials in the product: • Antimony • Lead • Cadmium • Silicon metal • Gallium • Silver • Indium • Tellurium For the encapsulant and backsheet the manufacturer shall also declare the type of polymers used (including if it is fluorinated or contains fluorinated additives) and the content in grams.

PART 1: FEEDBACK ON POLICY RECOMMENDATIONS

JMG Feedback

Issue	Recommendations & References
Module Option 2.2.1 Durability: IEC 61215 is a minimum requirement that all modules already have to fulfil. Not clear yet what has to be done in addition.	Compare which of the two standards, IEC TS 62941 and IECRE OD 405, is most likely to ensure permanent quality compliance (requirement of audits).
2.2.2 Lifetime performance degradation: Most modules do not have a performance warranty of 30 years. Validated field measurements are not representative. Values from different sites are not comparable, no generally valid degradation rate can be derived from them so far, the measurements take too long. Unvalidated data for degradation can be derived from accelerated measurements and simulations. So far, however, there is no generally valid procedure to determine degradation values in this way. Initial degradation in the first year is not to be reported.	Define minimum warranty requirements as part of Eco Design requirements. If these are not met, the module does not meet the Eco Design standard and should not be placed on the market. Until a commonly accepted standard for determining degradation values from acceleration measurements or field data is available, a common baseline degradation value (i.e. as specified in lifecycle assessment guidelines such as PEFCR) should be applied.
2.2.3 Reparability & 2.2.4 Dismantlability: Reparability refers not only to the individual module, but to the entire installation. It is important that a manufacturer offers the same type of module over many years, so that an installation can still be repaired. Further circularity criteria are needed.	Minimum requirements for the system components (such as minimum workmanship & performance warranty conditions) should be developed. Reparability & Dismantlability requirements should be defined for the complete system - as some components might not offer repair options, however, dismantling requirements should be mandatory information requirements for all components. Regarding specific requirements for junction boxes, at current state, 99% of PV junction boxes cannot be repaired, due to potting and the commoditization of the supply chain. Hence a reparability score on component level would initially disqualify the vast majority of producers and hence should be carefully assessed.
2.2.5 Material Disclosure: No standard has been proposed for which substances have to be disclosed. Constantly updating a specific list on EU Commission level may cause significant time lags and may therefore, be ineffective. In conjunction with the International Sustainability Leadership Standard NSF/ANSI 457 for Photovoltaic Modules and Inverters, a disclosure of substances used in the module should be encouraged.	In view of harmonising the requirements, disclosure of declarable substances should be in accordance with IEC 62474 declarable substance groups at the time the product is placed on the market. Photovoltaic specific materials which are not (yet) listed in the IEC 62474 inventory (such as specialty materials in compound semiconductors or dopants and fluorinated products used in some backsheet materials) could be added to inform recyclers on the presence of those additional materials. The specification of individual substance (group) disclosures of substances already covered in IEC 62474 should be dismissed instead, as the technologies are evolving very fast and use of certain substances changes. Furthermore, material disclosure is a "moving target", as REACH SVHC nominations and RoHS substance lists get extended. A reference to IEC 62474 would also ensure harmonization with the International Sustainability Leadership Standard and the EPEAT Ecolabel, as well as the Product Category Rules for PV developed under the Norwegian EPD program. Threshold values for declaration and information should also be in line with IEC 62474 at the time the product is placed on the market.
The current simple reference to standards (e.g. IEC 61215) allows significant room for interpretation applying conformity assessment (e.g. hailstone size)	Establish a comprehensive rating system that sets clear requirements for detailed assessment criteria to (IEC and other) standards. Participation of industry stakeholders contributing to the rating system development effort.
Inadequate and suboptimal use of recycling (and re-use) material	Resource depletion monitoring and min. recycled material content requirement should be addressed in a material efficiency evaluation per system component. Differentiation should be made according to ease of recycling, life cycle impact of recycled material (embodied energy & carbon, toxicity, particulate matter emissions etc.), and post-consumer or post-industrial origin.
Application of Environmental Product Declarations (EPD) and Product Category Rules (PCR) should be considered as implementing tools for material disclosure as well as sustainability indicators and metrics.	Environmental Product Declarations (EPD[16]) and Product Category Rules (PCR[17]) compliant with the requirements of EN 15804+A2:2019 can serve at least as monitoring tools, if not as a basis for setting mandatory or voluntary requirements. The PCR for PV modules used in the building and construction industry (NPCR 029:2020 Part B for photovoltaic modules) is in accordance with EN 15804 and was approved in June 2020 by EPD Norway. The PCR is global, valid for all, and the functional unit is Watt peak (W_p). This unit of measurement indicates how much power a panel can deliver under standardized conditions. There also exists a PCR for electricity generation from PV modules (PCR EPD Italy 014 – Photovoltaic modules), with the amount of kWh of electricity generated as a functional unit. The advantages of Watt peak as a functional unit is that it is independent of local solar irradiation, shade, temperature etc. However, the disadvantage of the functional unit Watt peak is that the lifetime performance is not reflected. An EPD based on NPCR 029:2020 provides figures of the environmental impact that are universal and easily comparable, independent of where the PV-panel is installed.

16 EPD is an independent, third party verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products, and is the most widespread documentation method for life-cycle based evaluation of environmental impact. It follows ISO 14025.

17 The Product Category Rule (PCR) is the "guideline" for the development of an EPD, which makes it possible to compare the environmental impact of two products of the same category.

PART 1: FEEDBACK ON POLICY RECOMMENDATIONS

Performance requirements on efficiency for PV Inverters

The task 8 report recommends calculating the 'Euro Efficiency' of an inverter based on the EN 50530 method, i.e. the removal of the worst performing, sub 94% efficient inverters would contribute as a minimum requirement for the inverter derating factor.

Performance aspect	Detailed proposed requirements
Euro Efficiency minimum requirement for PV inverters without storage	Require a minimum Euro Efficiency at Tier 1 of 94% and Tier 2 at 96% measured according to EN 50530. *Allowances shall be provided for micro-inverters and hybrid inverters to offset for their other benefits.*
Euro Efficiency supporting information requirement	In addition, the following supporting information shall be provided: • The efficiency values shall be presented in a tabulated form. • An annual temperature derating factor for the climate zones defined in IEC 61853-4 and calculated relative to 25°C
Efficiency requirements for PV inverters with the possibility to connect storage or with integrated storage	Require a minimum system efficiency of 90% at 25% of nominal power, at minimum MPP voltage with the battery at around 50% state of charge. Measurement to be made according to 'Efficiency guideline for PV storage systems 2.0'[18].
Smart readiness	Manufacturers shall ensure that the inverter supports class C data monitoring according to IEC 61724-1. The inverter shall have physical and/or wireless connectivity and be capable of communicating with other devices using the Modbus data transfer protocol in accordance with IEC 61158.

JMG Feedback

Issue	Recommendations & References
Euro Efficiency minimum requirement	The proposed minimum Euro Efficiency at Tier 1 of 94% and at Tier 2 of 96% are already very easy to achieve. More strict requirements should be considered to have a positive impact. Allowances to deviate from this requirement should only be considered for micro-inverters if there is a strong scientific demonstration/support that micro-inverters have other benefits for compensation.
No definition of minimum efficiencies for the different power paths for hybrid inverters (PV inverters with possibility to connect storage or with integrated storage)	For hybrid inverters it is suggested that minimum efficiencies for the different power paths are defined as they are, for example, in 'Efficiency guideline for PV storage systems 2.0'- Specifically, the path efficiencies PV2BAT, PV2AC and BAT2AC shall have minimum requirements, possible also AC2BAT if the inverter allows charging the battery from the grid. The minimum requirements can be derived by comparison with BATs, e.g. the HTW Berlin has performed extensive measurements/studies for the German market in 2018, 2019 and 2020[19].
Smart readiness "Manufacturers shall ensure that the inverter supports class C data monitoring according to IEC 61724-1."	Class C is planned to be deleted from Edition 2 of the standard. Class B as the next available option will require measurements of; in plane irradiation, PV module temperature, and monitor locally measured or remotely evaluated values of global horizontal irradiance and ambient air temperature. This may be appropriate for large scale plants, but not for small PV installations on private homes. Proposal: Change sentence to read as follows: Manufacturers shall ensure that the inverter or other usable equipment supports class B data monitoring according to IEC 61724-1 for PV plants > 40MW."
Smart readiness The inverter shall have physical and/or wireless connectivity and be capable of communicating with other devices using the Modbus data transfer protocol in accordance with IEC 61158.	Proposal: Delete reference to Modbus data transfer protocol. This very old-fashioned industrial communication fieldbus does not support cyber security requirements and is therefore not appropriate to be recommended.

19 https://pvspeicher.htw-berlin.de/speicher-inspektion-2020/ (in German)

Performance requirements on quality, durability and circularity for PV Inverters

The task 8 report recommends the introduction of a standardised basis for the minimum durability of inverters placed on the market, together with a focus on information about the repairability of the inverter.

Performance aspect	Detailed proposed requirements
Durability product test sequence	Each model shall be certified to have passed the product test sequence required for qualification under IEC 62093 clearly stating whether the product is for indoor or outdoor applications. *This requirement could be further extended to require factory quality controls and auditing according to IEC TS 63157 and the associated IECRE OD [pending a code].*
Additional information requirements	
Repairability requirements for inverters <30 kW	The manufacturer shall identify which of the circuit boards can be replaced on site.
Repairability requirements for inverters >30 kW	Manufacturers shall provide a preventative maintenance and replacement cycle. This shall include a list of parts that may be replaced and the timing of preventative measures to achieve a declared intended design technical lifetime (as required in IEC TS 63157). *Note: the possibility exists to include semi-quantitative criterion if a product specific standard is developed in accordance with the forthcoming horizontal standard for reparability prEN 45554*
Material disclosure	The manufacturer shall declare the content in grams of the following materials in the product as a whole and in the replaceable circuit boards: • Lead • Cadmium • Silicon carbide • Silver • Indium • Gallium • Tantalum

JMG Feedback

Issue	Recommendations & References
It is suggested that a reparability strategy is required for all inverters, but this should be distinguished from a maintenance plan, which should only be required for central inverters. Central inverters and string inverters could be differentiated by the mounting option (free standing or wall mounted).	Include all types of inverters with all associated power electronic components to be required to have a reparability strategy. Additional information shall be provided for possible obstacles during the repair (required special tools, an inconvenient common installation situation, or a lack of accessibility) which shall not exempt the requirement of reparability for all components.

Repair assessment unclear as it entails many variables: additional information shall be provided for possible obstacles during the repair (required special tools, an inconvenient common installation situation, or a lack of accessibility). The repair strategy also has to include additional equipment such as communication means or combiner boxes. Furthermore, in the current document a definition of "main parts" is missing. It is suggested to include all components that carry the main power flow in this list.	Form an expert group to define and establish sensible target process / system to ensure maximum repair options for inverters
Mention of "pending a code" in Table 8-4 and 8-8 while standards exist.	IECRE OD-41X-series can now be used instead of "pending a code" in Table 8-4 and 8-8.
In the "Material Disclosure" requirements, the relevance to disclose some specific element is not clearly indicated or established (for example with silicon carbide).	Add explanations why certain materials are significant to explain the relevance of each material which has to be disclosed. In view of harmonizing the requirements, disclosure of declarable substances should be in accordance with IEC 62474 declarable substance groups at the time the product is placed on the market. Specification of individual substance (group) disclosures instead should be dismissed, as the technologies are evolving very fast and use of certain substances changes. Furthermore, material disclosure is a "moving target" as REACH SVHC nominations and RoHS substance lists get extended. Threshold values for declaration and information should also be in line with IEC 62474 at the time the product is placed on the market.
Regarding material list disclosure: Constantly updating a list on EU Commission level may cause significant time lags and therefore, may be ineffective	Review whether IEC 62474 is sufficient or whether possibly, the standard needs further update, if so, trigger modification through IEC TC82. For material list, analyse the potential use of reference IEC 62474 (criteria 1, 2, 3) rather than a particular list under a EU directive.
The preparatory study mentions in '6.1.2.2.3 Repair' that fans shall be excluded as best inverter designs are without fans	The expert group disagrees with that statement. Good designs can include fans as the overall temperature can be reduced and therefore the lifetime can be increased significantly. Furthermore, passive cooling systems are also much bigger and can have a significant impact on material consumption and can also have a high energy footprint, e.g. aluminium. Passive cooled inverters can also suffer from dust accumulation and reduced cooling. It cannot be generally stated that good inverter designs are not using fans.

PART 1: FEEDBACK ON POLICY RECOMMENDATIONS

Life cycle GER and GWP information requirement

The task 8 report recommends establishing a standardized basis for the collection, analysis and presentation of module and inverter life cycle data and Life Cycle Assessment (LCA) results in the EU. The initial focus would be on two impact categories – primary energy (GER) and Global Warming Potential (GWP).

Performance aspect	Detailed proposed requirements
Life cycle GER and GWP product declaration	An Environmental Product Declaration (EPD) shall be prepared and provided for life cycle primary energy (GER) and Global Warming Potential (GWP) (as a minimum) and at the latest by [delayed year of introduction] and for a representative product from each module series placed on the market. *For further discussion: options are for the EPD to be in conformity with EN 15804 or the PEFCR and to have been registered with a Type III Product Category Rules operator.*

JMG Feedback

Issue	Recommendations & References
No guidance/timeline for the development of more EPDs for system components with precise milestones / goals.	It is suggested a timeline for the development of more EPDs and (harmonized) PCRs for system components (PV Panels, Inverters, BOS components) with precise milestones / goals is provided. They can be further used as KPIs. Furthermore, PCRs (i.e. NPCR 029:2020 Part B for photovoltaic modules, PCR EPD Italy 014 – Photovoltaic modules) which have been developed in accordance with EN15804 should be harmonized across the EU to ensure validity and comparability across all EPD systems.
Many goals or targets currently leave too much room for interpretation which might lead circumvention or non-compliance with the intended purpose.	Create clear deliverables for conformity assessment and rating standards, e. g. under the IECRE conformity assessment system PCR/EPD, PEFCR/Green Claims regulatory frameworks. Generally, set clear (sufficiently detailed) goals, targets and guidelines that can be consistently followed, monitored, and enforced.
The scope of environmental impacts is limited to two impact categories (GWP and GER) while there are many other impacts such as toxicity, particulate matter, acidification- impact categories according to EU PEF Guidance. The current recommendation lacks a reference to a standard for LCA calculation / GWP calculation / GER calculation.	In order to apply a more holistic approach, some further environmental category impacts should also be considered (regarding toxicity, particulate matter, acidification…). This will make sure the scope of environmental impacts includes all relevant impact categories. Furthermore, clear guidelines should be provided regarding the methodology to be used, in order to ensure consistent comparisons/interpretations and common tools. Provide a comprehensive method adequately representing all environmental impacts, e. g. represented by an environmental impact index (EII). Besides defining a GER and GWP information requirement, based on the applicable methodological references, additional KPIs might be defined to align the information requirements with other methodological references applied in the product group, such as EPEAT PVMI requirements (based on NSF/ANSI 457-2019), the PEFCR PV Electricity and Corporate Social Responsibility disclosure requirements in line with the NFRD. Set up a task force that defines the metrics to develop an EII requirements catalogue and rating system to derive a comprehensive system. Furthermore, an independent conformity assessment body needs to be established or an existing body such as IECRE should be mandated to operate a conformity assessment system. Define which standards are to be used for reporting the required data and metrics (EN 15804, PEF Guidance & PERCR, ISO standard 14040-4, IEA PVPS12 Methodology Guidelines for LCA on PV, EPD PCRs, IEC standards etc.) In addition to the proposed indicators on gross energy consumption and global warming potential, the JMG considers the following impact categories as relevant for the characterization of the sustainability of PV systems: (1) freshwater eco-toxicity, (2) particulate matter emissions, (3) Resource depletion (mineral, fossil, renewable). The calculation of relevant LCA indicators (such as GWP in CO2-eq/kWh) should be done assuming a reference location (average of EU) and the lifetime energy yield consistent with the references used for the energy label calculations. The embodied carbon emissions / carbon footprint should be stated. This is also important in the context of increasing interest and requirements for scope-3 reporting, and to allow the distinction between the production phase (specific to the product) and the use phase (specific to the site/project). As mentioned above, the EPD NPCR 029:2020 Part B for photovoltaic modules for example can be used since the functional unit is Watt peak (Wp). CO2-eq/Wp makes it also simpler as it is independent of local solar irradiation, shade, temperature etc., providing figures of the environmental impact of the product that are universal and easily comparable, independent of where the PV-panel is installed. Regarding the supply chain of electricity, the grid mix of the country related to the respective life cycle stage should be used; the consideration of renewable power purchase agreements or bundled/unbundled RECs should not be permitted.

Recommendation 2: Energy Label for residential systems

The task 8 report recommends the establishment of an Energy Label for solar PV systems that is targeted at systems installed on residential buildings – referring to any building, public or private, that is intended for use as a permanent dwelling. This shall include Building Integrated Photovoltaic (BIPV) systems made up of one discrete array consisting of a homogenous PV product. For simplicity, it is proposed that the labelling requirements would be placed on the as-built rather than the monitored performance of a system. It is also proposed that systems that incorporate Building Integrated (BIPV) photovoltaic arrays could be labelled.

Performance aspect	Detailed proposed requirements
System yield-based Energy Efficiency Index (EEI)	The system provider shall follow instructions for the calculation of the overall yield derived from the module yield and Performance Ratio for the system design. In addition, the yield shall be calculated on the following basis according to the transitional method: • For a notional 30-year service life. • For the closest representative EU climate zone. • By applying the listed derating factors, together with prescribed (default) values, which will be provided in the Implementing Regulation. The EEI shall be expressed in units of MWh/(kWp x m^2).
NOTE: the present analysis deals with techno-economic aspects. In parallel, a check is ongoing on the legal feasibility of an Energy labelling scheme for PV products/system, in the form of a delegated act in the framework of Regulation 2017/1369	

JMG Feedback

Issue	Recommendations & References
LCOE calculation misses the discounting of the denominator (sum of electrical energy generation).	Regulation and supporting study should apply a harmonized LCOE calculation. LCOE calculation results should also be harmonized with yield calculation results for reference systems with given components.
Preparatory study only reflects results of literature surveys. Missing data & long regulatory development process make it difficult to reference the latest state-of-knowledge.	Latest available material should be referenced in the supporting study development process (i.e. VDMA ITRPV, PVthin, SolarPower Europe). This would ensure technical product parameters (i.e. wafer thickness) used for calculation, and definition of thresholds are representative of state-of-the-art when defining base cases and BAT / BNAT references.
System yield (as in the EEI) and component output power are mixed up. The system yield has to be defined for a number of standard configurations and reference climates. The configurations provided should go beyond the ideally tilted and oriented rooftop installation and take due consideration of east-west, vertical facade, horizontal flat rooftop and mixed installations.	There should be a clear distinction between system yield and component output power that is consistently applied across the policy instruments. The regulatory proposal should include benchmarks and examples of system yields including different component output power ratings in different configurations.
EEI calculation relies on default degradation rates and BOS loss factors. Comprehensive (and statistically backed) PLRs are not considered.	Performance Loss Rates (PLRs) should be used instead of module degradation / default BOS loss factors as stipulated in Lindig et.al. (2019)[20]
No benchmarks (with state-of-the-art yield assessment tools) or example calculations provided in transitional methods report or system calculation tool (should be in Appendix).	Transitional methods for the calculation of EEI should provide benchmarks and reference calculations for standard and non-standard system configurations (in Appendix 2 of this document) to make calculation of EEI easier for installers. Calculation examples incorporating non-standard configurations (east-west, facade, flat roof) to enable site-specific validation of EEI in comparison to commonly used energy prediction software . The application of IEC 61853-4 to define the reference climates for the calculation of the energy yield for the reference systems should be reconsidered, as the respective climate zones / latitudes provided to not provide sufficient granularity to be representative for the EU. A potential alternative which could provide more geographic granularity could be the GIS based online tool from the JRC[22].
EEI is only calculated for the use phase, using yield estimates and disregarding embodied energy of the production / end-of-life stages.	EEI should incorporate energy efficiency of production and end-of-life stages and not only the use phase. Part 2 provides a recommendation on the inclusion of an EROI / EPBT term into the EEI calculation to reflect energy efficiency of production and recycling processes and lever circularity and advanced manufacturing technologies.
BIPV Inclusion- Current methodology does not take into consideration of the multi-functionality of BIPV systems. An EEI calculation performed for a BIPV system would also need to consider the Energy Efficiency of a “non-active” building component, such as a brick wall, in comparison to the BIPV system, which offers this additional functionality.	Due to fundamental differences in functional units and reference systems, the JMG strongly proposes to exclude BIPV applications from the scope of the Energy Label. Recommendation would be to utilize the definition of EN 50583-1:2016 “Photovoltaics in buildings – Part 1: BIPV modules” to formulate the exclusion. Refer to EPD and NPCR 029 v1.1[23] for PV (EPD Norway).
Operating framework for establishment of EEI / energy label validation not specified	Validation & operating framework for the conformity assessment of issued energy labels should be established. Potentially use an internationally accepted conformity assessment system such as IECRE or others. Standardize the calculation methodology for the system level Energy Label including the data matrix for its individual components (modules and power conversion equipment). Create an EN standard developed under CENELEC TC82 and an IECRE OD adopting the calculation methodology of the JRC computation formula (including loss factors, configurations etc.). A software module based on that standard could be integrated within commonly available energy prediction software packages to define the outcome for the label. This software module would be subject to certification by accepted certification bodies under a conformity assessment system such as IECRE, TEXXECURE rating system or others. Possible pathway: Step 1: EN standard for the calculation methodology. Application & conformity ensured through certification bodies. Parallel/aligned approach: CENELEC to start to work out the standard and IECRE (or any alternative conformity assessment system) to refer to that standard, e.g. in the provisionally reserved IECRE OD-412 series. Step 2: Escalate to IEC TC82 to adopt the EN Standard to become an IEC standard at a later stage (independent of the EU process).and Market Analyst, SolarPower Europe, Brussels, Belgium

[20] *Lindig, Sascha, David Moser, Alan J. Curran, und Roger H. French. „Performance Loss Rates of PV systems of Task 13 database". In 2019 IEEE 46th Photovoltaic Specialists Conference (PVSC), 1363–67. Chicago, IL, USA: IEEE, 2019. https://doi.org/10.1109/PVSC40753.2019.8980638.*

[21] *i.e. PVSYST, PVSOL, Plant Predict*

[22] *https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP*

[23] *PRODUCT CATEGORY RULES EN 15804 NPCR 029 version 1.1 - PCR – Part B for photovoltaic modules used in the building and construction industry, including production of cell, wafer, ingot block, solar grade silicon, solar substrates, solar superstrates and other solar grade semiconductor materials*

PART 2: ADDITIONAL RECOMMENDATIONS

PART 2: ADDITIONAL RECOMMENDATIONS

Following the progress of the stakeholder discussions in the Joint Mission Group and the kick-off of the dedicated supporting study work for the proposed policy measures by the Joint Research Centres in Ispra (Italy) and Seville (Spain) as announced during the stakeholders webinar, the following additional recommendations pertaining Eco-Design requirements for PV modules and inverters, as well as considerations and calculations on a potential Energy Label for residential photovoltaic systems are provided in this part of the Expert Input Paper.

Additionally, a holistic approach for the sustainability evaluation in the form of an Environmental Impact Index (EII) is proposed and referenced to applicable standards and methodologies. This Environmental Impact Index would satisfy the information requirements lined out in the policy recommendations and would help to trigger consumer interest as well as market pull for more sustainable products. Ultimately, further discussions of the EEI framework - potentially also including quality and reliability requirements - could lead to the definition of multi-dimensional green public procurement requirements for PV electricity (and components) in the EU, satisfying the objectives of the EU Green Deal & Green Recovery ambitions.

Eco-Design for Photovoltaic Modules

The service life and degradation of a solar module determine the life-time total energy yield that a module generates. These two parameters therefore determine the environmental impact of the generated electricity to a considerable extent. In the current proposal, a lifetime of 30 years is assumed for all module technologies. Degradation can be determined according to a proposed measurement procedure. However, according to the authors, there is no scientifically accepted procedure. The proposed procedure is therefore unreliable and time-consuming. Alternatively, technologies are assigned to two different categories. For crystalline silicon solar modules, an annual degradation of 0.7% is assumed. For thin-film modules, an annual degradation of 1.0 % is assumed, where modules based on crystalline silicon hetero-junction solar cells also fall into this category.

Both the assumption for the lifetime and the assumption for the degradation do not reflect current technological differences. For example, glass-glass modules show very low degradation and long lifetimes. Silicon hetero-junction solar modules are offered in the market with an annual degradation warranty of 0.25 %.

In principle, the following procedures are conceivable for determining the service life and the degradation of a solar module:

1. Same lifetime for all technologies, different degradation rates for different technology categories (part of the current proposal).
2. Lifetime and degradation from the manufacturer's performance warranty. Here it is important that the minimum warranty conditions are clearly defined in the Eco-Design specifications (replacement or repair for the first years, financial compensation thereafter, define measurement procedures in accordance with standards, take measurement uncertainties into consideration).
3. Different lifetimes and degradation for different technology categories should be based on validated data in conformance with available and future standards, specifically determining degradation rates and expected lifetimes.
4. Metrological determination of the service life and the degradation.

The expert panel evaluated the different approaches according to the following criteria: (i) effort for the module manufacturer in terms of cost and time, (ii) comprehensive consideration of all technological differences, (iii) need for regular revision, (iv) a scientifically accepted procedure is available, (v) benefit for the customer. The evaluation is summarized in the following table.

Table 1: Module lifetime degradation – Assessment grades from 1 (very negative) to 5 (very positive).

	Effort for the Manufacturer (cost, time)	Considers Quality Differences	Effort for Regular Revision	Accepted Standard / Data Availability	Usefulness for the Costumer	Mean Value of the Assessment
Option A (same for all)	4	1	2	1	1	1,8
Option B (warranty)	3	4	4	3	4	3,6
Option C (classes)	4	2	2	2	2	2,4
Option D (measurement)	1	4	4	1	4	2,8

Assessment from 1 (very negative) to 5 (very positive)

Option 1 does not take qualitative differences (reliability) of the modules into account, it has no added value for the module costumer. Option 3 also does not consider qualitative differences of modules. Allocation, regular adjustment and verification are very costly. The customer has no added value. Option 4 is very costly for the module manufacturer, qualitative differences would be proven, regular adjustment and review would not be necessary and the added value for the customer would be very high as qualitative differences are made visible. However, the authors are not aware of any scientifically recognized procedure so far, and the procedure would also be too time-consuming. The experts therefore strongly recommend option 2. A performance guarantee for module degradation and service life will be complied by the module manufacturers, otherwise they have to replace the modules in the event of reduced performance. Therefore, the manufacturer will carefully set the guaranteed degradation and lifetime and carry out appropriate tests. However, it is very important that the minimum guarantee requirements are comprehensively defined in the eco-design directive.

Eco-Design for Photovoltaic Inverters

One of the most important measures to reduce the environmental impact of photovoltaic inverters is its lifetime. As this is very difficult to estimate or guarantee at the time when the inverter is placed on the market, we suggest focusing on its reparability. This should not be met by defining minimum warranty requirements for inverters, as this could lead to negative incentives such as to plan to replace the inverter during the warranty time which could increase the overall footprint.

In order to promote reparability of photovoltaic inverters, and therefore to increase their lifespan, the Eco-Design measures should ensure the availability of spare parts and that the inverter is constructed to allow access to and replacement of identified parts, in particular that spare parts are available over a long period of time after purchase:

- 15 years minimum for all electronic / electro-mechanical components of the inverter.
- this includes the software needed for the full function[24] of the device.
- at least each individual printed circuit board and disconnectable[25] component must be provided as independent spare part.
- moreover, during that period, the manufacturer shall ensure the delivery of the spare parts within 15 working days within Europe.

Spare parts can be replaced with the use of commonly available tools* and without permanent damage to the inverter. In order to enhance the repair market, manufacturers have to ensure the availability of repair and- maintenance information for professional repairers.

24 This can be either the binary codes in order to flash the individual micro-controllers / ICs or the pre-programmed micro-controllers / ICs / printed circuit boards
25 Without damaging the component or the rest of the inverter

Energy Label for residential-scale systems

The policy recommendation on the introduction of an energy label, suggests a label for the entire solar photovoltaic system deployed on residential rooftops. Here, many factors such as the energy yield of the module, the efficiency of the inverter, the orientation of the module and the location are taken into account. Given the overarching policy objective to improve the sustainability performance of the different system components, the proposed methodology for the determination of the energy performance falls short on its ability to provide component level differentiation. In order to support the customer and the installer in the selection process of components, we suggest an energy label at the module level to be very important. Through this, modules with a better energy yield will also be rated better, which directly influences the purchasing behaviour.

Furthermore, the introduction of an energy label for building integrated photovoltaic systems should be reconsidered, until a holistic evaluation methodology for building products has been developed, which also enables the validation of additional functionalities provided by BIPV elements and to avoid creating disincentives for the building integration of photovoltaics.

The system energy label regarding the expected energy yield for a given location and installation should be complemented by an Environmental Impact Index, which evaluates the environmental impact of module, inverter & balance of system production, operation and disposal, in the various impact categories. The assessment should be based on harmonized PCRs or PEFCRs that are valid in all EU countries. The assessment method must be standardized, clear, cost-effective and simple – a proposal for implementation is provided in the paragraph on the proposed Environmental Impact Index.

It is important that unbundled renewable energy certificates are excluded in the supply chain of electricity for module production and rather the country's electricity mix has to be used to prevent double counting or misallocation of lifecycle impacts. In addition, it should be considered whether ESG (environment, social and governance) criteria should be taken into account for the assessment of manufacturing and the manufacturer in order to promote an ecological, social and transparent way of doing business in the EU.

To inform the future discussions on the development of a calculation methodology for residential scale photovoltaic systems, the Joint Mission Group has performed a number of benchmark calculations for reference systems, using the specified PV System Calculator as well as commercial energy yield prediction and assessment tools. The detailed calculations are available in the Annex of this Expert Input Paper.

Operating system example

General remarks

To enable a true statement of sustainability a multi-pronged approach has been concluded to be the best possible solution. Sustainability is ultimately a combination of

1. reliability and high quality, which suggests safe components and systems with a long lifetime,
2. environmental compatibility by good lifecycle management from sourcing and production through final disposal, including but not limited to management of substances and processes used (non-hazardous, abundant availability, recycled content), reusability, repairability, recyclability,
3. social responsibility also on a corporate level, across borders, and
4. a monitoring system for the best available technology (BAT) to make sure that components and systems are manufactured and deployed representing state-of-the art technologies when it comes to the above aspects and to specific performance.

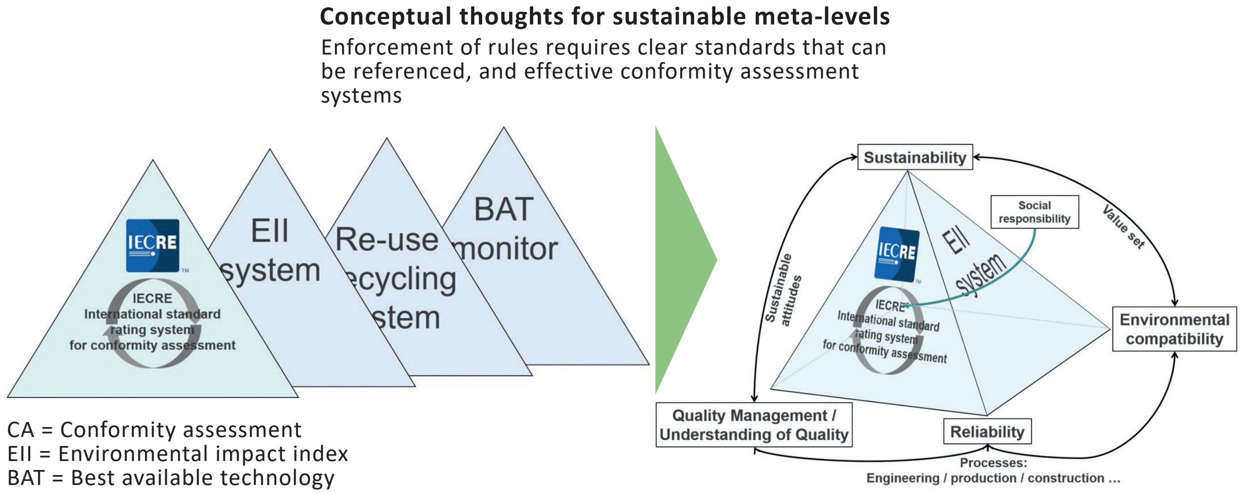


Figure 2: Conceptual thoughts for sustainability meta-levels

Conceptually, to visualize this train of thought, a sustainability pyramid has been developed. The pyramid consists of four sides,

1. The quality management represented by the IECRE conformity assessment (and later, rating) system or by equivalently accepted conformity assessment and rating systems,
2. The Environmental Impact Index discussed in the subsequent chapter,
3. The re-use and recycling system, and
4. The best available technology monitoring system.

In any event, whether for quality and safety related aspects or for the other sustainability aspects outlined above, conformity assessment or- in the case of BAT- recurring monitoring at suitable intervals are essential (at least from a certain minimum system size upwards), or else any requirements may simply rely solely on self-declaration, and as a consequence, may not be sufficiently tangible. Naturally, the level of effort, and in turn cost to establish any conformity statement needs to be put into the context of the level of investment. The following image (Fig. 3) depicts the concept whereby small, residential-scale systems would be required to provide a more simplistic way to establish evidence of conformity than a large utility-scale system, noting that there are several steps in-between.

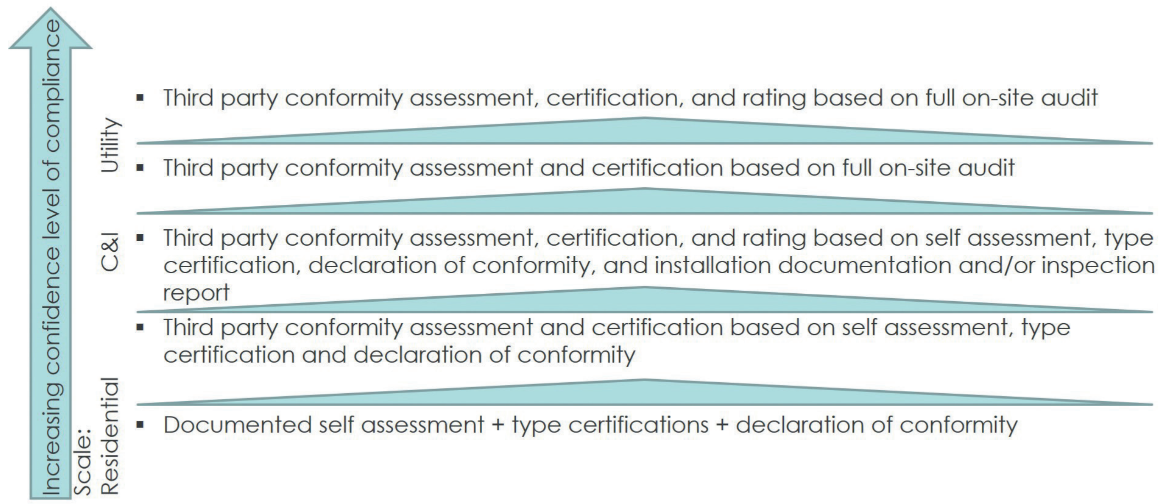


Figure 3: Confidence levels of compliance

* Third party refers to an independent assessor approved under an accepted system
** On-site audits: In above chart, "on-site" refers to the PV power plant site

Manufacturer assessment should always be performed by a third party for product pre-qualification under an IECRE, TEXXECURE, or other applicable rating systems as well as for EII, both for existing products as well as for forecasted products during the product development phase as of TRL 5/6 (technology readiness level 5/6: technology demonstration) as far as relevant for tender participation.

For projects subject to GPP (typically utility scale projects), evidence of compliance from a planning stage shall be given at the time of submission of an offer to a tender, and upon completion subjected to on-site assessment for verification of compliance.

Overall, while the first generation rating system at TEXXECURE (a candidate for the IECRE rating system under development) is ready for beta-testing, and already includes the individual component level as well as the PV system level, the EII system as well as the BAT monitoring system still need to be further developed. These systems are quite complex, however, if sufficient resources are allocated, it can be developed in a matter of approx. 1- 1.5 years provided all participants agree and adhere to an accelerated development program.

IECRE / TEXXECURE rating scheme

IECRE is the IEC system for certification to standards relating to equipment for use in renewable energy applications. In other words, it is the conformity assessment system for renewable energy sources operated under IEC, the International Electrotechnical Commission.

Currently, under task force 6 of IECRE, a rating system is being developed.

The current concept for the rating system is illustrated in the following figures (Fig. 4 and Fig. 5):

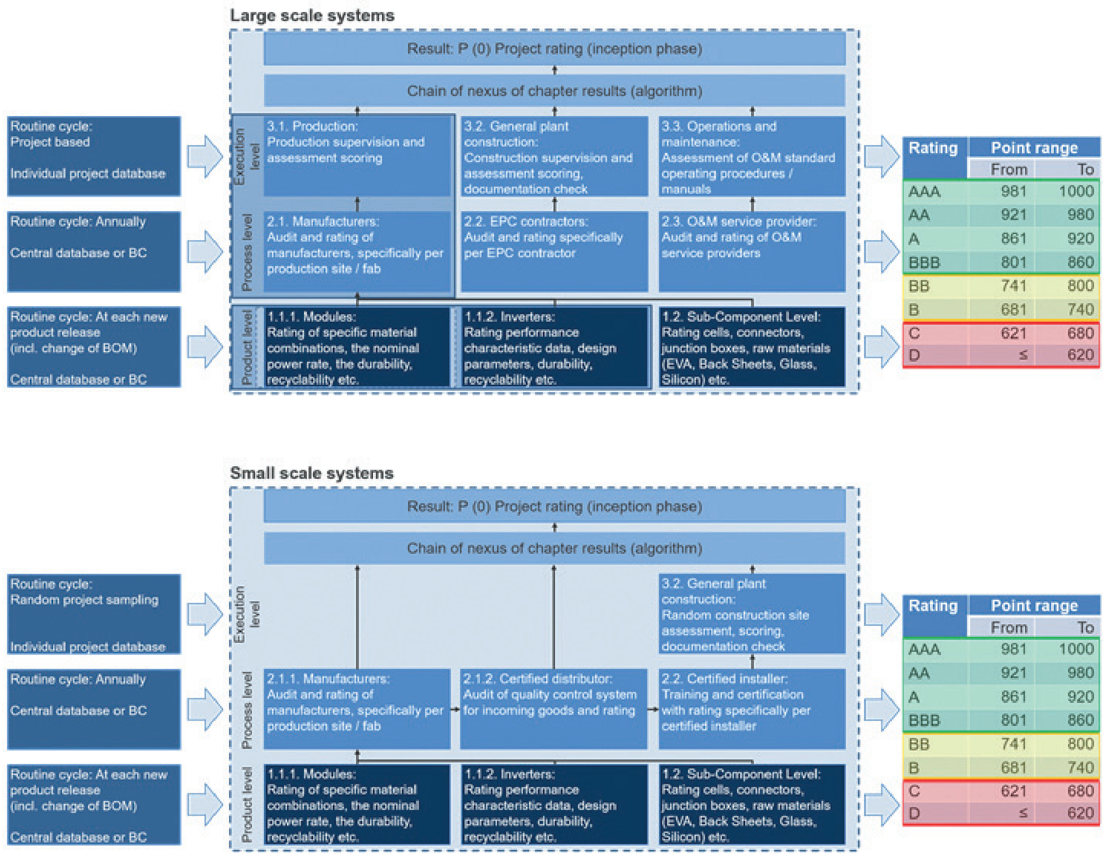


Figure 4 & 5: Source: EXXERGY, TEXXECURE Rating Foundation

A PV power plant is a system that is characterized by the inter-operation of components that have been:

- specified in the design of a PV power plant;
- procured- subject to possible operational changes during the procurement processes in case of unforeseen challenges (e. g. component availability at time of dispatch request);
- constructed according to the construction guidelines and international and local codes and standards.

The key is that individual components (product) may be evidently sustainable and made of good quality, however, the assembly of components and the way the system has been designed and constructed may not, e.g. because of component mismatch. As an example, the performance of a string is typically determined by the lowest performing module in the string. Therefore, it is important to operate a system that considers not only the individual component but the sub-systems and the entire system, as illustrated above.

Further to system considerations, inclination, orientation, shadowing and many other aspects play a role in assessing the sustainability of a PV power plant. Another important aspect is different climatic conditions. Up until recently, the international standards have not taken climate related challenges into consideration. The newly developed IEC TS 62126 that was issued in June 2020 provides modified testing conditions for modules that will be deployed in climates that have an environmental air temperature higher than 40 °C and/or for module installation methods that restrict cooling, resulting in higher operational temperatures than anticipated in the originating standards.

These aspects are all reflected in the rating system outlined above that is conceptually designed to reflect on different meta-levels:

A. The product, process, and execution levels:
   a. The product level is designed to establish a product type rating.
   b. The process level is designed to establish a manufacturer process rating, generally following the philosophy of the requirements according to regulation 2006/95/EC and 2014/35/EU.
   c. The execution level is designed to establish the rating for the actual production lot or construction. This is to ensure primarily that the rating established on the previous levels can actually be confirmed

B. Lifetime levels:
   a. The inception phase is defined as the phase from project development through commissioning.
   b. The exploitation phase is defined as the phase from commissioning through decommissioning, usually 20+ years => Review of the existing rating resulting either in confirmation or in adjustment.
   c. The decommissioning phase can turn into re-use, recycling, or disposal, for each of these either entirely or in part.

C. Climate and site-specific conditions: In the current design, the rating system differentiates between 5 climate zones. IEC 61853-4 will be adopted to reflect these different climate zones (then a total of 6). In addition to climate zones, site specific conditions are reflected in the rating system, e. g. near shore, agricultural environment, desert with sand, hail prone areas etc.

D. Project size:
   a. Residential scale, for example up to 20 kW_p
   b. Commercial and industrial scale, for example from 10 kW_p to approx. 10 MW_p
   c. Utility scale, larger than 10 MWp, often 3-digit MW_p

The routine cycles to perform a rating are outlined on the left-hand side of the above-mentioned figure.

The rating classification is conceptually designed to translate a complex technical context into a language that the investment community is accustomed to. Therefore, the rating classifications have a certain meaning:

- AAA- BBB Investment grades
- BB- B Non-investment grade, however, fulfilling minimum safety and IEC standards.
- C- D Fail to meet standards.

More to the applicability in the context of the Eco-Design, Energy Label, and GPP, see next page.

Holistic evaluation of sustainability performance - Environmental Impact Index (EII)

Like the rating system outlined above, the environmental impact of a PV power plant requires a system perspective. Naturally, the environmental impact of each component is an indispensable compliance criterion, however, it is ultimately the entire system that needs to comply just as well with sustainability criteria.

That said the environmental impact of any product or system is a quite complex task to assess. It requires in itself a multi-pronged review of any product or project. On the other hand, it is important to understand the environmental impact in an easy-to-comprehend way. To translate the complexity of an environmental assessment into an abbreviated form, developing and establishing an effective environmental impact index is strongly suggested. The "Environmental Impact Index" (abbreviation: "EII") shall hence mean a unique index by which the various influencing factors of industrial or other human activity to the environment are condensed in a summarizing, comprehensive index in a way that the impact of such activity can be reconstructed and evaluated.

The expert group suggests the development of such an EII in close cooperation between the standardization body called for by the EU Commission and an industrial expert group that can be managed by a neutral (non-profit) entity such as for example TEXXECURE Rating Foundation.

In order to reinforce the aim of reducing the impact of industrial and other human activity on the planet, clear rules, procedures, and standards must be set against which conformity assessment and monitoring systems can be established. Therefore, the expert group suggests the following terms of reference of the EII system:

- To provide a consensus based EII system based on established (or to be established) methods, including but not limited to PEFCR v.1.1, NPCR 029 v.1.1, EPEAT PVMI based on NSF/ANSI 457, CSR guidelines and IEA PVPS Task 12 Methodology Guidelines;
- To define the relevant bodies, their requirements, and their roles and responsibilities to enable an EII system;
- To define the rules of procedure to set up, operate, and maintain an EII system that includes conformity assessment and monitoring; and
- To propose the operational documents and deliverables defining the processes and requirements for establishing the EII system, reflecting with weighted final results on how to establish a final EII.

Generally, the EII could either consist of a single letter or of a combination of several letters, one for each category, to provide a more differentiated declaration. In the following, the concept is explained at the example of modules and inverters.

The proposed scale would be in alphabetical order from A through G, providing guidance with the following interpretation:

- Levels A, B: Pass for GPP and ED/EL requirements
- Levels C, D: Pass for ED/EL requirements, fail for GPP requirements
- Level E: Fail for GPP, ED/EL requirements with minor deficiencies
- Levels F, G: Fail for GPP, ED/EL requirements with medium / major deficiencies

The differentiation for the levels E, F, and G (all "fail to meet requirements") would trigger staged consequences. Level E is suggested to result in a conformity re-assessment just for the category within 3 months to enable min. D provided that the conformity re-assessment would prove compliance. For GPP, see below recommendation. Levels F and G would suggest medium and major deficiencies that would require complete conformity re-assessments in all categories.

The Annex of this paper- Technical Documentation- gives examples for modules and inverters as they reflect the majority of a PV power plant system. The concept for the EII system for PV power plants still needs to be developed, however, it would fundamentally follow the analogous logic as for PV modules and inverters taking other considerations into account, in particular performance related criteria (e. g. deriving from orientation, inclination, shading) that can be drawn e. g. from the rating system or a system simulation.

GPP & Ecolabelling recommendations

The expert team recommends the following requirements for GPP and Eco Label:

EII minimum classification of "B" in every single category. As a transitional method, for some selected categories, a classification of "D" can be considered for an intermediate period of 2 years following the enactment of the directive. Operationally – for example through continuous evaluation through an existing conformity assurance framework as described above – the Commission could establish a revolving white list of producers at the time of GPP tenders. It has to be taken into consideration that Producers can be changed at the time of project completion (it may take 24 months after awarding), only and only if the producers are not existing anymore or not fulfilling the standards anymore.

As certification is costly and technology evolving fast, the certification at the time of bidding won't be valid for the products delivered in the future (product lifetime = 6-12 months before modification and new IEC/RE) It avoids project developers to change module suppliers at the last minute with new comers reaching requirements 12-24 months after bidding.

Recommendation to include CSR (Corporate Social Responsibility) criteria

RATIONALES TO IMPLEMENT CSR CRITERIA

Context – CSR & European initiatives

Considering the EU strategy on promoting CSR and encouraging businesses to adhere to international guidelines[26], several initiatives have been launched starting from the EC communication 2011[27], to the directive 2014/95/EU[28] and the study commissioned by EU parliament 2020[29]. CSR and RBC (Responsible Business Conduct) have been clearly identified as the core concepts to manage the negative impacts on society and environment by preventing and mitigating them including the global supply chain. The last study published in November 2020, covers the international law instruments on CSR from the UNGPs[30](United Nations Guiding Principles on business & human rights), the ILO - MNE Declaration[31] (International Labour Organization – Multinational Enterprises) and the OECD guidelines and guidance[32] (Organization for Economic Co-operation and Development). The international instruments are considered as "minimum thresholds the companies can take into account in the context of CSR debate". As a strong support of the United Nations 2030 Agenda for sustainable Development and associated Sustainable Development Goals (SDGs), the European Commission "has taken a very active approach to CSR at EU level". The EU analysis in the context of the COVID crisis has raised that the implementation of CSR within companies implies extra costs, however, creates in parallel significant value creation in terms of innovation and benefits. Moreover, the European Commission has raised the clear demand of the citizens for sustainable business initiatives. Accelerating the incentives on CSR legislative approach, the European Commission has announced the revision process 2014/95/EU in 2020 to "strengthen the foundations for sustainable investment".

CSR as critical asset to support investment of the energy sector

The development of sustainable finance, so called green financing models based on ESG (Environmental, Social & Governance) is expanding very rapidly and will necessarily impact the energy sector investment framework. Indeed, on the front line, and to answer the carbon neutrality target, renewable energy investments are expected to be one of the most important release of funds in the coming years. Many European oil companies such as BP (UK), Shell (UK/NL), Eni (Italy), Total (France), Respol (Spain), Equinor (Norway) have announced in 2020 that their objectives to significantly reduce their oil and gas activities. In the meanwhile announcing their intentions to invest massively in low-emission activities, including mostly renewable energies. This type of investment will necessarily be deployed in the context of green financing. The photovoltaic sector will have to meet sustainability criteria including social criteria that are required to access financing from the "sustainable" taxonomy and integrate the portfolios of major financial institutions.

26 Corporate Social Responsibility – Recommendations to the European Commission By the subgroup on « CSR » of the Multi-Stakeholders Platform on the Implementation of the SDGs in the EU https://ec.europa.eu/info/sites/info/files/recommendations-subgroup-corporate-social-responsibility_en.pdf

27 Directive 2014/95/EU amending directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0681:FIN:EN:PDF

28 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0095&from=EN

29 Corporate social responsibility (CSR) and its implementation into EU Company law https://www.europarl.europa.eu/RegData/etudes/STUD/2020/658541/IPOL_STU(2020)658541_EN.pdf

30 United Nations Guiding Principles on business & human rights https://www.ohchr.org/Documents/Publications/GuidingPrinciplesBusinessHR_EN.pdf

31 Tripartite Declaration of Principles concerning Multinational Enterprises and Social Policy (MNE Declaration) - 5th Edition (2017) https://www.ilo.org/empent/areas/mne-declaration/lang--en/index.htm

32 OECD – Guidelines for Multinational Entreprises http://www.oecd.org/daf/inv/mne/48004323.pdf & OECD - Due Diligence Guidance for RBC http://mneguidelines.oecd.org/OECD-Due-Diligence-Guidance-for-Responsible-Business-Conduct.pdf

ANNEX: ADDITIONAL TECHNICAL DOCUMENTATION

This Annex provides both the results of a benchmark calculation of the energy efficiency index / lifetime energy yield utilizing and recommendations and considerations to help frame the discussion on potential environmental impact indicators.

Energy Efficiency Index Benchmark calculations

This section provides the results of a benchmark calculation of the energy efficiency index / lifetime energy yield utilizing the PV system calculation tool provided by the JRC and commercial yield prediction tools for a number of reference systems, with different module & inverter technologies and system configurations.

The following benchmarks were calculated applying PVSYST and PlantPredict:

Ref.	Climate Zone	Location	Orientation (0 = South)	Inclination	Technology		
1	Subtropical arid	Murcia	0	20	CdTe	CIGS	crystalline silicon
2		Murcia	0	90	CdTe	CIGS	crystalline silicon
3		Murcia	45	20	CdTe	CIGS	crystalline silicon
4		Murcia	45	90	CdTe	CIGS	crystalline silicon
5	Temperate coastal	Stockholm	0	30	CdTe	CIGS	crystalline silicon
6		Stockholm	0	90	CdTe	CIGS	crystalline silicon
7		Stockholm	45	30	CdTe	CIGS	crystalline silicon
8		Stockholm	45	90	CdTe	CIGS	crystalline silicon
9	Temperate continental	Berlin	0	40	CdTe	CIGS	crystalline silicon
10		Berlin	0	90	CdTe	CIGS	crystalline silicon
11		Berlin	45	40	CdTe	CIGS	crystalline silicon
12		Berlin	45	90	CdTe	CIGS	crystalline silicon

Recommendation 1: The equation used in the Solar PV system tool has an issue related to the final step in the EEY calculation. In fact, the Lifetime AC energy yield is divided by the nominal power and by the PV system area. The issue is highlighted in the following table where two hypothetical system with the same technological combination and system layout would have 2 different EEY.

nominal power	area/kWp	area*power	yield	energy	EEY whole area	EEY unit area
1	5	5	1000	1000	6000	6000
2	10	20	1000	2000	3000	6000

The suggestion would be to divide by the nominal power and the unit area (area needed to have 1 kWp); however, we would like to stress that if calculated in this way the results would essentially be lifetime yield per unit area, kWh/m^2 and it is the equivalent of dividing the lifetime AC energy yield by only the whole area of the PV system.

Reference 1 - PlantPredict[33] - applied to CdTe technology case, assuming minimum loss values

This benchmark was carried out by First Solar energy yield prediction experts, using the latest module performance files in the latest version of PlantPredict and comparing the results to the lifetime energy yield results from the Solar PV System Tool developed by the EC Joint Research Center.

First Solar Series 6 PV module (430 Wp)
Azimuth=0°
Tilt=20 / 30 / 40°, as per climate
Minimum loss values used

Reference Climatic Profile	Solar PV System Tool Results		Plant Predict Results		Energy difference (Tool as reference) [%]	Rating Change?
	Lifetime Energy [kWh/kWp·m^2]	Grade	Lifetime Energy [kWh/kWp·m^2]	Grade		
Subtropical Arid	1926,9	D	1843,8	E	-4,3%	Yes, D → E
Temperate Coastal	875,1	D	803,4	E	-8,2%	Yes, D → E
Temperate Continental	1114,4	D	1067,4	D	-4,2%	No

33 www.plantpredict.com

Azimuth=0°
Tilt=90°
Minimum loss values used

Reference Climatic Profile	Solar PV System Tool Results		Plant Predict Results		Energy difference (Solar PV System Tool as reference) [%]	Rating Change?
	Lifetime Energy [kWh/kWp·m^2]	Rating	Lifetime Energy [kWh/kWp·m^2]	Rating		
Subtropical Arid	1909,6	D	1797,0	E	-5,9%	Yes, D → E
Temperate Coastal	863,2	D	776,0	E	-10,1%	Yes, D → E
Temperate Continental	1101,2	D	1045,3	E	-5,1%	Yes, D → E

Azimuth=45°
Tilt=20 / 30 / 40°, as per climate
Minimum loss values used

Reference Climatic Profile	Solar PV System Tool Results		Plant Predict Results		Energy difference (Solar PV System Tool as reference) [%]	Rating Change?
	Lifetime Energy [kWh/kWp·m^2]	Rating	Lifetime Energy [kWh/kWp·m^2]	Rating		
Subtropical Arid	1919,3	D	1832,7	E	-4,5%	Yes, D → E
Temperate Coastal	870,1	D	799,5	E	-8,1%	Yes, D → E
Temperate Continental	1106,6	D	1057,3	D	-4,5%	No

Azimuth=45°
Tilt=90°
Minimum loss values used

Reference Climatic Profile	Solar PV System Tool Results		Plant Predict Results		Energy difference (Solar PV System Tool as reference) [%]	Rating Change?
	Lifetime Energy [kWh/kWp·m^2]	Rating	Lifetime Energy [kWh/kWp·m^2]	Rating		
Subtropical Arid	1897,7	D	1794,9	E	-5,4%	Yes, D → E
Temperate Coastal	856,3	D	775,2	E	-9,5%	Yes, D → E
Temperate Continental	1089,7	D	1037,2	E	-4,8%	Yes, D → E

ANNEX: ADDITIONAL TECHNICAL DOCUMENTATION

As demonstrated above for the case of minimal system loss values, the Solar PV System Tool systematically overestimates the lifetime energy of the referenced PV system. That effect is more pronounced in temperate costal climate and would in almost all cases lead to a different Energy Efficiency Index rating (applying the proposed scale), if the commercial energy yield prediction software would be used.

Reference 2 – SAM[34] – applied to all technology cases

The second reference calculation was done for all PV technology cases, using a different set of input data for the module technology characteristics (PAN files) in the SAM database. The climatic data for the 3 sites (Murcia, Stockholm, Berlin) were taken from PVGIS, using TMY 2007-2016 ECMWF/ERA database. The results are shown below using unit area instead of whole area:

SAM [kWh/m²]			Solar PV System Tool Results [kWh/m²]			Energy difference (Solar PV System Tool as reference) [%]		
MiaSole FLEX-03 320 W	FirstSolar FS4122-3	Jinko JKM405M-72HL-V	MiaSole FLEX-03 320 W	FirstSolar FS4122-3	Jinko JKM405M-72HL-V			
SMA SB5000 TL	SMA SB5000 TL	SMA SB5000 TL	SMA SB5000 TL	SMA SB5000 TL	SMA SB5000 TL			
6286	7790	9232	6541	7690	9363	4%	-1%	1%
4154	5096	5993	4307	5076	6180	4%	0%	3%
5721	7082	8376	5920	6976	8493	3%	-2%	1%
3458	4240	4964	3528	4157	5061	2%	-2%	2%
3918	4646	5583	4240	4997	6084	8%	7%	8%
2962	3536	4179	3191	3761	4578	7%	6%	9%
3328	3993	4725	3579	4217	5134	7%	5%	8%
2395	2861	3369	2561	3018	3675	6%	5%	8%
3577	4326	5115	3643	4293	5227	2%	-1%	2%
2549	3068	3608	2599	3063	3729	2%	0%	3%
3074	3717	4382	3118	3674	4474	1%	-1%	2%
2093	2521	2952	2119	2497	3040	1%	-1%	3%
Subtropical Arid / Row 1: 0, 20 (Orientation, Azimuth) / Row 2: 0, 90 / Row 3: 45, 20 / Row 4: 45, 90								
Temperate Costal / Row 1: 0, 20 (Orientation, Azimuth) / Row 2: 0, 90 / Row 3: 45, 20 / Row 4: 45, 90								
Temperate Continental / Row 1: 0, 20 (Orientation, Azimuth) / Row 2: 0, 90 / Row 3: 45, 20 / Row 4: 45, 90								

34 https://sam.nrel.gov/

This benchmark indicates that the differences between technologies by varying tilt angle and azimuth remains similar in relative terms using the PV system tool (unless the system losses are changed on a case by case basis) (for example the difference between CIGS and CdTe is around-18%, the difference between CdTe and c-Si is around-22%). Instead using an yield assessment tools the difference between technologies for various tilt angle and orientation can be reduced and in the situation of PV modules with similar efficiencies, it might be the case that the ranking given by the solar PV system tool does not hold when an yield assessment tool is used. This benchmark was calculated using typical values for system losses:

- Module mismatch: 2%
- DC wiring: 2%
- Diodes & connectors: 0.5%
- Soiling: 5%
- Shading: 5%
- AC wiring: 1%
- Inverter temperature derating: 1%

Furthermore, similar degradation rates (0.5% p.a.) and reference service lifetimes (30 years) were assumed.

Recommendation 2: Based on the initial benchmark calculations and the application of the system tool, it is recommended to further refine the PV System tool, also for a better modelling of inverters and potential other components (e.g. Module Level Power Conversion Equipment).

Recommendation 3: The EEY as it is conceived at the moment will always favour system with optimal angle and optimal orientation. However, in residential system, roofs and facades are the constraints and optimal tilt and angle lose their meaning. For this reason, one could explore other metrics that allow to rank technologies within a certain given tilt angle and azimuth, for example by introducing a Lifetime efficiency that could be defined as EEY lifetime energy (as currently calculated) divide by the lifetime insolation on the plane of array normalized over the whole area.

							Lifetime efficiency	
						EEY Lifetime energy / Lifetime insolation / whole area		
						1	2	3
						MiaSole FLEX-03 320 W	FirstSolar FS4122-3	Jinko JKM405M-72HL-V
						SMA SB5000 TL	SMA SB5000 TL	SMA SB5000 TL
1	Subtropical arid	Murcia	0	20	2015	10.4%	12.9%	15.3%
2		Murcia	0	90	1342	10.3%	12.7%	14.9%
3		Murcia	45	20	1835	10.4%	12.9%	15.2%
4		Murcia	45	90	1106	10.4%	12.8%	15.0%
5	Temperate coastal	Stockholm	0	40	1168	11.2%	13.3%	15.9%
6		Stockholm	0	90	889	11.1%	13.3%	15.7%
7		Stockholm	45	40	993	11.2%	13.4%	15.9%
8		Stockholm	45	90	718	11.1%	13.3%	15.6%
9	Temperate continental	Berlin	0	40	1088	11.0%	13.3%	15.7%
10		Berlin	0	90	785	10.8%	13.0%	15.3%
11		Berlin	45	40	938	10.9%	13.2%	15.6%
12		Berlin	45	90	644	10.8%	13.1%	15.3%

ANNEX: ADDITIONAL TECHNICAL DOCUMENTATION

Environmental Criteria for PV Modules & Inverters

Based on the discussions in the expert group on sustainability criteria, the following recommendations and considerations have been compiled to help frame the discussion on potential environmental impact indicators which could be developed in conjunction with an Energy Efficiency Label.

Environmental Criteria for PV Modules

For PV modules, 6 different categories have been identified, 2 of which may be considered to be reflected in the Energy Label (EL), namely GWP and GER, and the others to be considered to be reflected in the Ecodesign (ED) requirements, namely HAZ (hazardous substances), RECY (recycled content), and REPA (recyclability and repairability), and QUAL (quality, IECRE, TEXXECURE, or other generally accepted international or European conformity assessment system), see also below table.

Criteria / Policy Tool Implementation	Life Cycle GWP / embodied carbon / carbon footprint	Life Cycle GER / Energy Payback Time (EPBT)	Hazardous Substances	Recycled Content	Recyclability & Repairability	Quality (IECRE / TEXXECURE)
Proposed Scale	A - G	A - G	A - G	A - G	A - G	A - G
Information Requirement under ED* / EL **	EL	EL	ED	ED	ED	ED
Minimum Requirement Eco-Design (ED) Energy Label (EL)	D	D	D	D	D	D
Visibility on extended Energy Label (EL)	YES	YES	NO	NO	NO	NO
GPP Award Criteria	B	B	B	B	B	B

* It is assumed that Eco-Design compliance is demonstrated through self declaration / CE marking
** It is assumed that Energy Label claims are validated through independent 3rd parties and through dedidated product group standards based on horizontal standards

Figure 5: Example for an integrated Environmental Impact Index for PV Modules

To establish the applicable rating from the scale, the development of a scoring system is recommended to enable the introduction and the operation of an EII system.

To establish the applicable rating from the scale, the development of a scoring system is recommended to enable the introduction and the operation of an EII system.

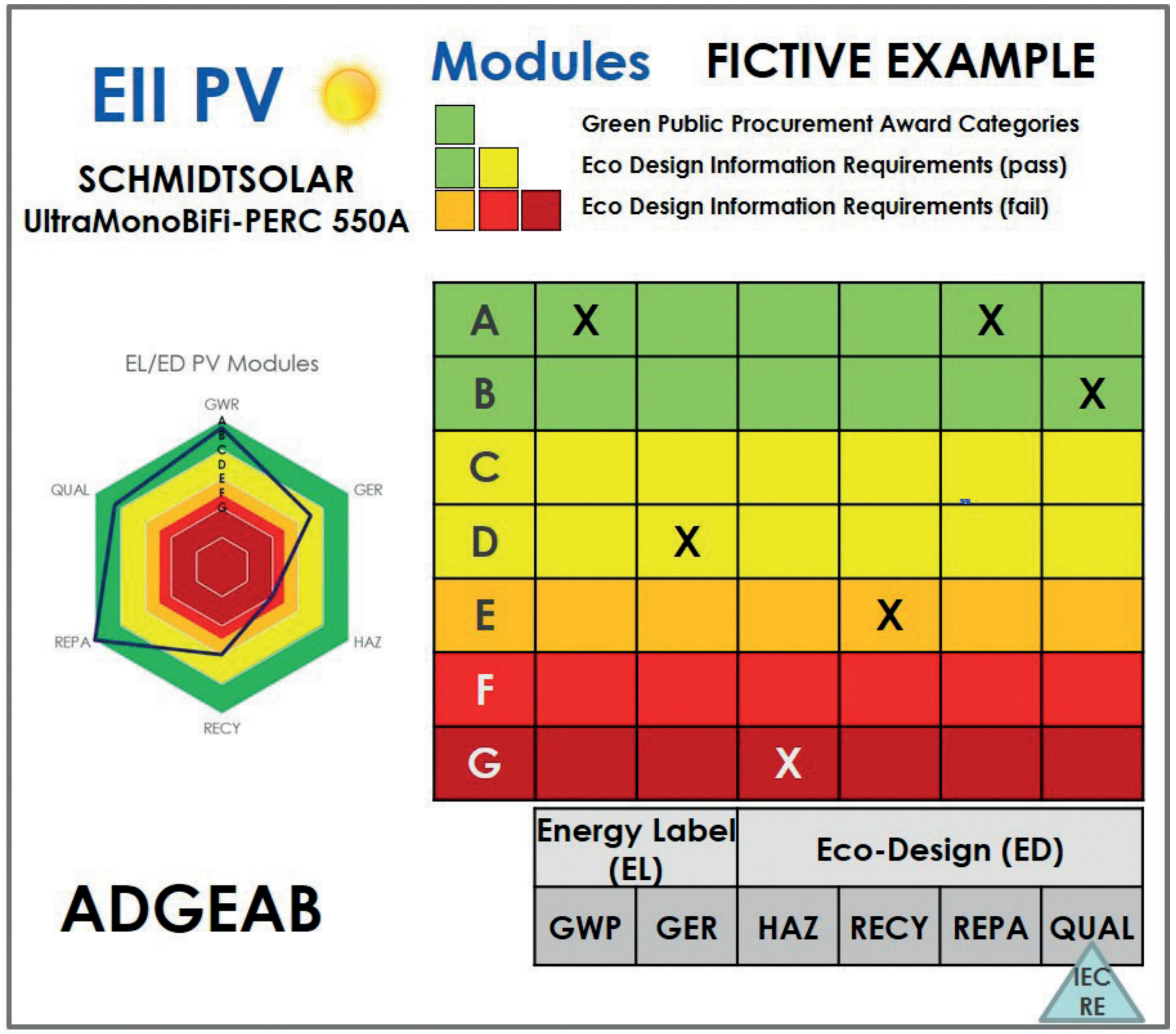


Figure 6:Example for an integrated Environmental Impact Index for PV Modules

The table on the next page lists first thoughts about recommended references and proposes a baseline grading as a starting point for further discussions in the context of the supporting study. This needs to be worked out further, naturally.

Category	GWP [kg CO_2eq/kWp]*		GER		HAZ	RECY	REPA	QUAL
Rating	Min	Max	Min	Max		Min	Min	IECRE / TEXXECURE Rating
A		250	tbd	tbd	B + NSF 457 5.2.4	B + > 10% post-consumer recycled content (excl. glass)	B + junction box, bypass diodes	AAA
B	250	300	tbd	tbd	C + NSF 457 5.2.3	C + > 10% recycled semiconductor	C + backsheet	AA
C	300	350	tbd	tbd	D + NSF 457 5.1.5 + 5.1.6	D + > 10% recycled paste, contact materials (incl. TCO)	D + Cells	A
D	350	400	tbd	tbd	E + NSF 457 5.1.4	E + > 25% recycled frame material	Glass (repair kit) and frame	BBB
E	400	475	tbd	tbd	F + NSF 457 5.1.3	F + > 10 % recycled backsheet/encapsulant	Non-repairable	BB
F	475	550	tbd	tbd	G + NSF 457 5.2.1 + 5.2.2	G + > 50% recycled glass (internal and external cullet) => Check for applicability given the need for low iron glass	Non-repairable	B
G	550		tbd	tbd	NSF457 - 5.1.1 + 5.1.2 / Decl Subst List - IEC 62474 / REACH SVHCs	Declaration of recycled content	Non-repairable	C, D
	* Reference to anticipated lifetime kWh may be more effective: [kg CO²eq/lifetime kWh]					Comment: Either ramp up by component or by an overall increasing %-age of total recycled content (e. g. starting with 0% for F and G, 10% for E, etc. up to 50% for A, in addition to glass and Al that will get a min. recycling rate for D rating). For Si, make reference to kerf recycling recommendation?		

Regarding the remark related to GWP and whether the referenced functional unit Wp might ideally be replaced by kWh, for a product (e. g. module) it will be difficult to establish a relation for kWh. However, the anticipated kWh generated over the lifetime of a device can be established as a function based on average irradiation - or even more preferable based on the 6 climate zones based on IEC 61853 - and manufacturer guaranteed performance period and degradation. The formula would then relate to lifetime kWh, and therefore, at least provide guidance on actual lifetime performance. A possible formula based on carbon footprint per lifetime kWh could be established as follows:

$GWP = 1000 * CF / (IR_x * NP * GP * \sum (1-DEG_i))$ [kg CO_2eq / kWh]

with

CF	=	LCA Carbon Footprint incl. manufacture, ship, installation, maintenance, and end-of-life processing of a device [kg CO_2eq]
IRx	=	Irradiation of reference place (or average irradiation considered) [kWh/(kW$_p$ * year)]
NP	=	Nominal power of a device [W$_p$]
GP	=	Guarantee period of the manufacturer [years], maximum 20 years
DEGi	=	Degradation in year i [%]
∑	=	Sum for the years i = 1 to GP

More specifically, the following table outlines further details for all categories:

<table>
<tr><th>Indicator</th><th>Proposal</th></tr>
<tr><td>GWP - Global Warming Potential</td><td>Required Validation: Third party reviewed life cycle assessment in accordance with NSF457 Criterion 7.1.1 or NPCR 029 v.1.1 - OR - application of tabulated GWPij values of module components i, based on production location j. Life Cycle Inventory Data Quality requirements in conjunction with PEFCR v.1.1, Chapter 5.4 - minimum DQR level: 1.6.</td></tr>
<tr><td>GER - Gross Energy Requirement</td><td>A detailed standard methodology for the calculation of the GER for photovoltaic modules and inverters still has not been defined yet. Proposal would be to use the nr-CED (non-renewable cumulative energy demand) as defined in the IEA PVPS Task 12 reference methodology on Net Energy Analysis (to be updated by Q1 2021).
<table>
<tr><th>Metric</th><th>$EROI_{el}$</th><th>$EROI_{PE-eq}$</th><th>CED</th><th>nr-CED</th></tr>
<tr><td>Formula</td><td>$\frac{Out_{el}}{Inv}$</td><td>$\frac{Out_{PE-eq}}{Inv} = \frac{(Out_{el}/\eta_G)}{Inv}$</td><td>$\frac{(PE+Inv)}{Out_{el}}$</td><td>$\frac{(PE_{nr}+Inv_{nr})}{Out_{el}}$</td></tr>
<tr><td>Units</td><td>[MJ / MJ]</td><td>[MJ / MJ]</td><td>[MJ / MJ]</td><td>[MJ / MJ]</td></tr>
<tr><td>Meaning of the numerator</td><td>Energy delivered ('returned') to society, in units of electricity</td><td>Energy delivered ('returned') to society, in units of equivalent primary energy</td><td>Total primary energy harvested from nature</td><td>Non-renewable primary energy harvested from nature</td></tr>
<tr><td>Meaning of the denominator</td><td colspan="2">Sum of energy carriers diverted from other societal uses (excluding energy delivered to society), in terms of their total primary energy demand</td><td colspan="2">Energy delivered ('returned') to society, in units of electricity</td></tr>
<tr><td>Distinction between renewable and non-renewable energy?</td><td colspan="2">No, not normally made</td><td colspan="2">Yes, generally recommended</td></tr>
<tr><td>Main purpose</td><td colspan="2">Economical/effective use of available energy carriers</td><td>Efficient use of primary energy resources</td><td>Sustainable/ efficient use of non-renewable primary energy resources</td></tr>
<tr><td>Temporal perspective</td><td colspan="2">Short term</td><td colspan="2">Long term</td></tr>
</table></td></tr>
<tr><td>Hazardous Substance Disclosure</td><td>Proposed disclosure in conjunction with NSF 457 Criteria 5.1.1 to 5.1.6 and 5.2.1 - 5.2.4 for PV Modules and PV Inverters, as well as in conjunction with NPCR 029 v.1.1 criteria 7.4 - minimum disclosure requirements aligned with IEC 62474 Declarable Substance List and respective concentration thresholds, REACH SVHC List and REACH Candidate List</td></tr>
<tr><td>Recycled Content Disclosure</td><td>Proposed disclosure in conjunction with NSF457 Criteria 6.1.1 and 6.1.2 - Declaration of recycled content in product.</td></tr>
<tr><td>Reparability & Recyclability</td><td>A detailed standard methodology for the determination of the repair- and recyclability for photovoltaic modules and inverters still has not been defined. It is proposed to develop those vertical product group standards in conjunction with the existing horizontal standards for electronic products IEC 45552 through IEC 45559.
<table>
<tr><td>EN 45552:2020 (WI=JT010003)
General method for the assessment of the durability of energy-related products</td><td>2020-03-11</td></tr>
<tr><td>EN 45553:2020 (WI=65686)
General method for the assessment of the ability to remanufacture energy-related products</td><td>2020-07-10</td></tr>
<tr><td>EN 45554:2020 (WI=65685)
General methods for the assessment of the ability to repair, reuse and upgrade energy-related products</td><td>2020-02-21</td></tr>
<tr><td>EN 45555:2019 (WI=JT010001)
General methods for assessing the recyclability and recoverability of energy-related products</td><td>2019-11-27</td></tr>
<tr><td>EN 45556:2019 (WI=65709)
General method for assessing the proportion of reused components in energy-related products</td><td>2019-06-07</td></tr>
<tr><td>EN 45557:2020 (WI=JT010002)
General method for assessing the proportion of recycled material content in energy-related products</td><td>2020-04-29</td></tr>
<tr><td>EN 45558:2019 (WI=65687)
General method to declare the use of critical raw materials in energy-related products</td><td>2019-03-01</td></tr>
<tr><td>EN 45559:2019 (WI=65688)
Methods for providing information relating to material efficiency aspects of energy-related products</td><td>2019-03-01</td></tr>
</table></td></tr>
<tr><td>QUAL - Rating</td><td>See table above and chapter "IECRE / TEXXECURE rating scheme"</td></tr>
</table>

Environmental Criteria for Inverters

For PV inverters, eight different categories have been identified, two of which may be considered to be reflected in the Energy Label (EL), namely GWP and GER, and the others to be considered to be reflected in the Eco-Design (ED) requirements, namely MOS (management of substances), RECY1 (recycled content), RECY2 (design for recycling), SSC (sustainable supply chain), REPA (repairability), and QUAL (quality, IECRE, TEXXECURE, or other generally accepted international or European conformity assessment system). The table below represents a suggestion on a first train of thought basis and therefore, needs to be further developed.

Min required	Aspects for discussion	References / Standards
CO2-Footprint GWP, GER?	It is important, which methodology is used for assessing any environmental aspect	Similar to modules, based on NSF457 or similar
Management of substances MOS	MoS is more comprehensive, not only consider on hazardous materials but also critical raw materials, recyclability, reparability, environmental impact at disposal etc.	EN 45558 (01.03.2019) declare the use of critical raw materials Ellen McArthur Foundation re circular economy
Recycled Content RECY1	Similar to NSF 457	EN 45557 (29.04.2020) proportion of recycled material content
Design for Recycling RECY2	How to define a recycling quota, is there an international standard?	EN 45553 (10.07.2020) ability to remanufacture EN 45555 (27.11.2020) recyclability and recoverability
Sustainable supply chain SSC	Question, how to measure it. Because there are several labels for suppliers and we have to use a harmonized system.	Assessment standard Ecovadis or comparable?
Lifetime and Reparability REPA	There is a connection between this two aspects to consider the lifetime. How to measure it? Lifetime and reparability are the two biggest influencing points for the quality / durability of the Inverter.	Do, and if so, which standards exist? EN 45552 (11.03.2020) durability EN 45554 (21.02.2020) repair reuse and upgrade EN 45556 (07.06.2020) proportion of re used components
QUAL	Rating system, to be discussed in WG II	IECRE or TEXXECURE

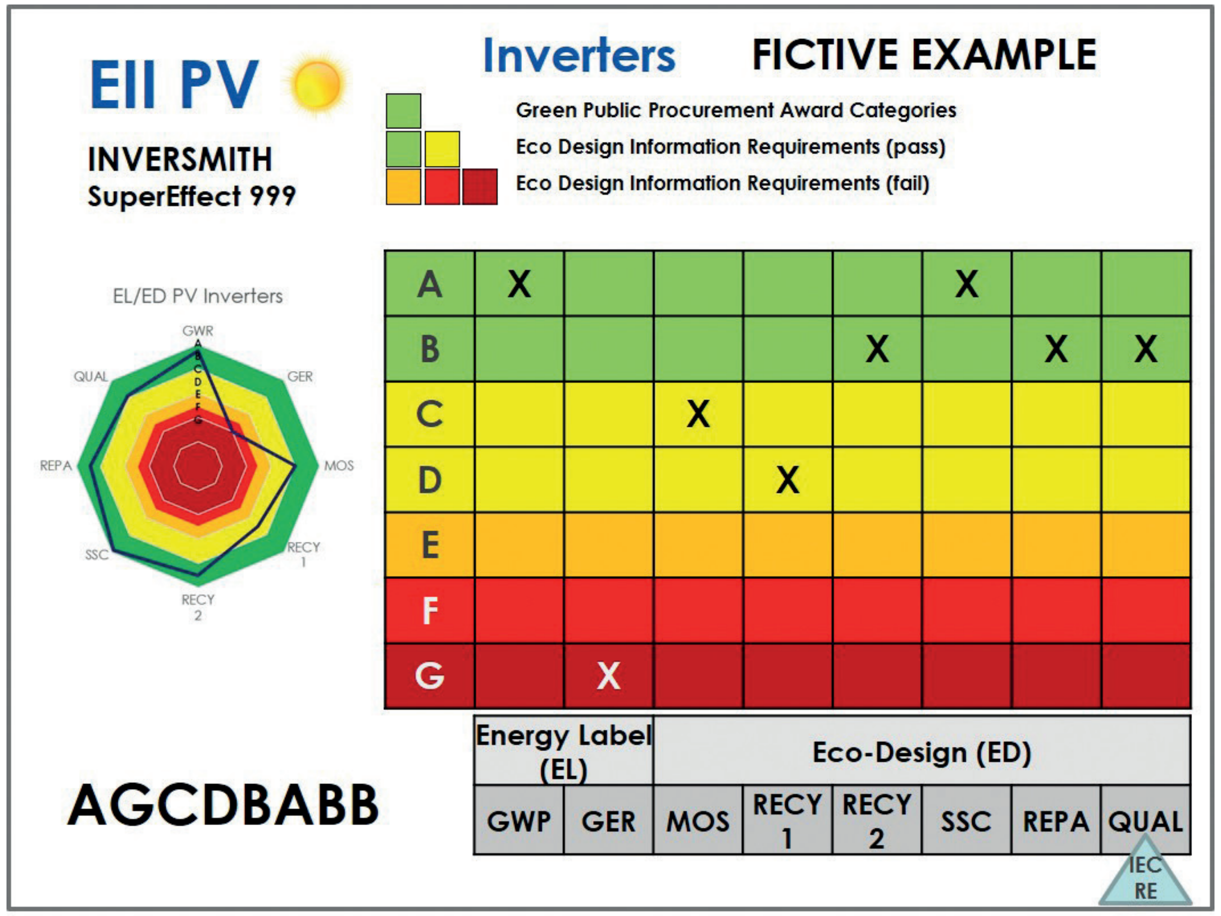
The general concept for evaluation criteria is comparable to the one for module criteria, see below table.

Criteria / Policy Tool Implementation	Life Cycle GWP / embodied carbon / carbon footprint	Life Cycle GER / Energy Payback Time (EPBT)	Management of Substances	Recycled Content	Design for Recycling	Sustainable Supply Chain	Lifetime & Repairability	Quality (IECRE / TEXXECURE)
Proposed Scale	A - G	A - G	A - G	A - G	A - G	A - G	A - G	A - G
Information Requirement under ED* / EL **	EL	EL	ED	ED	ED	ED	ED	ED
Minimum Requirement Eco-Design (ED) Energy Label (EL)	D	D	D	D	D	D	D	D
Visibility on extended Energy Label (EL)	YES	YES	NO	NO	NO	NO	NO	NO
GPP Award Criteria	B	B	B	B	B	B	B	B

* IT is assumed that Eco-Design compliance is demonstrated through self declaration / CE marking
** IT is assumed that Energy Label claims are validated through independent 3rd parties and through dedidated product group standards based on horizontal standards

To establish the applicable rating from the scale, the development of a scoring system is recommended to enable the introduction and the operation of an EII system.

The visualization of the EII could follow either one of the designs below, depicting a fictive example, or both in parallel:



Further details need to be developed. RECY2 (design for recycling) may turn out not be needed as it is covered already by the WEEE directive.

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