Discussion paper on potential Ecodesign requirements and Energy Labelling scheme(s) for photovoltaic modules, inverters and systems

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1. Introduction and Objectives

1.1. Introduction

Making sure that newly-installed photovoltaic (PV) products (modules, inverters and installations) in the European Union (EU) produce clean energy efficiently and are environmentally sustainable is of primary importance, given the role that this technology is expected to have in the decarbonisation of the EU energy system.

The current market situation for photovoltaic products (modules, inverters and systems) is such that:

- there is the need to ensure comparability in the market between claims relating to module energy yield, module's performance long-term degradation and life-cycle energy impacts. Moreover, not all products on the market feature high quality and long-term energy performance.
- modules and inverters are manufactured and designed in such a way that it is often difficult to repair and recycle them.
- solar inverters have a key role to play in the smart readiness of homes but this is not currently a standardised feature.
- the energy yield of photovoltaic systems can potentially be shifted upwards through a combination of:
    - better design –to take into account site-specific conditions,
    - best installation practices and
    - reduced losses thanks to the implementation of best practices in selecting and coupling the proper equipment with adequate cabling and maintenance.

Regulatory measures in the field of sustainable product policy – notably Ecodesign and Energy Labelling - could be instrumental to this extent, to ensure the environmental sustainability of PVs by improving their environmental performance as well as their energy yield, in turn reducing the overall life cycle environmental footprint of the products deployed in the field, with the aim to:

- foster module and inverter designs that have improved long-term energy yield, circularity, footprint and smart readiness.
- take products off the market that are of a low quality and that have higher life cycle costs.
- optimise and increase the energy yield of residential installations by enabling consumers to make an informed choice based on the performance of system designs offered by retailers and installers.

Two initiatives on the environmental impact of PV products have been officially announced at Commission level[1], and the Commission is currently working for defining how the policy measures – in reply to the abovementioned understanding of the PV market situation at EU level – would look like, and for estimating the related impacts.

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[1] See at https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12819-Environmental-impact-of-photovoltaic-modules-inverters-and-systems-Ecodesign and at https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12820-Environmental-impact-of-photovoltaic-modules-inverters-and-systems-Energy-Labelling

1.2. Aim of the document

Within the scenario described in the previous subsection, this discussion paper is aimed to develop a technical and legal analysis on the feasibility and formulation of Ecodesign requirements and Energy Labelling schemes for PV products, also with the view to foster feedback and views by stakeholders. The technical knowledge basis for this work is mainly deriving from dedicated studies by the Joint Research (JRC):

- A preparatory study[2] (referred to as 'the preparatory study' in the remainder of the text) offering a comprehensive techno-economic and environmental assessment for PV products in order to provide policy makers with the evidence basis for assessing whether to implement four policy instruments: Ecodesign, Energy Label, Ecolabel and Green Public Procurement (GPP);
- A technical study[3] on the standards for the assessment of the environmental performance of PV products.

The studies also benefited from feedback received from 3 stakeholder meetings.

The regulatory approaches discussed in the present document can be summarised as follows:

- Some of the Ecodesign requirements hereby presented are 'traditional' ones, affecting either the energy efficiency of PV products (such as the euroefficiency of inverters) or material efficiency aspects such as repairability and recyclability.
- In line with the findings of the JRC preparatory study, there are two categories of requirements/conformity assessment procedures that were never enacted so far within Ecodesign measures, namely on:
    - information regarding the environmental footprint ('ecological profile' as per the definitions laid down in the Ecodesign Directive 2009/125) of the manufacturing phase of PV modules and inverters;
    - the quality control of the manufacturing process of PV modules and inverters.

  Given the innovative nature of such regulatory solutions, dedicated analyses on policy as well as legal aspects are developed. To this extent, potential regulatory approaches are sketched in the document. The aim is not to give a finalised legal formulation, rather to identify the main elements to be further developed.
- the proposed Energy Labelling schemes for PV modules and systems have specific features, when compared to products already regulated with an energy label[4], as they would target energy *generating* products.

2. ECODESIGN REQUIREMENTS FOR MODULES

The following requirements are proposed to be set and applied to individual PV modules that are placed on the EU market and intended for use in photovoltaic systems for grid-connected electricity generation. Specifically excluded from the scope would be the following products/categories:

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[2] https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/2020-12/jrc12431preparatory_study_for_solar_photovoltaic_modules_kj-na-30468-en.pdf

[3] https://ec.europa.eu/jrc/en/publication/standards-assessment-environmental-performance-photovoltaic modules-power-conversion-equipment-and

[4] See at https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/energy-efficient-products_en

- Modules with a DC output power of less than 50 Watts under Standard Test Conditions (STC)

- Photovoltaic modules used as construction products (building integrated photovoltaics, i.e. BIPV) i.e. providing a function as defined in the European Construction Product Regulation CPR 305/2011. Building-attached PV (BAPV) products are in scope unless excluded by other criteria specified here. PV modules that are out on the market for both BIPV and non-BIPV applications shall meet Ecodesign requirements

- PV module designs integrated into consumer electronic products, or other multifunctional applications requiring specialised designs for which energy production is not the only purpose/functionality e.g. street furniture, large-area shading, specific agri-PV applications or other similar.

Special considerations must be followed in the case of special products:

- For modules containing integrated or embedded micro-inverters, the modules and inverters should be labelled or characterised in accordance to the Ecodesign and Energy label regulation before the integration occurs.
- For PV modules manufactured with new technologies entering the market, with scope for rapidly increasing efficiency or demonstrating long-term reliability, with the aim of not dissuading innovation.

2.1. Requirement on electricity yield

Performance aspect	**Detailed proposed requirements**
Module energy yield	The module energy output (yield) expressed in kWh/kWp and calculated according to EN IEC 61853-3 for each of the three reference EU climatic profiles (Subtropical arid, Temperate continental and Temperate coastal), as defined in EN IEC 61853-4 The requirement could be set as either information or minimum threshold (also linked to energy labelling developments). A transition method will be available for bifacial modules.

The proposed approach is for an Ecodesign requirement based on a declaration (information requirement) or threshold (quantitative requirement) for the energy yield calculated according to EN IEC 61853-3 and with reference to the three PV reference climatic profiles defined in EN IEC 61853-4 that best represent European climates, i.e. Subtropical arid, Temperate coastal and Temperature continental. The reason for selecting this option is that it is more representative of the performance under real life conditions. In addition to the energy rating it takes into account PV module performance characteristics such as spectral responsivity and the potential loss of performance at high temperatures or under low light conditions.

2.2. REQUIREMENT ON DURABILITY

Performance aspect	Detailed proposed requirements
Design qualification for long-term operation	From XX YY 20ZZ, manufacturers, importers or authorised representatives shall ensure that PV modules are capable to withstand prolonged exposure in open-air climates, in line with the following functional requirements: SEE ANNEX A Part 1

This potential Ecodesign requirement would introduce a stringent set of quality and durability tests for PV modules. The design qualification of PV modules according to the EN IEC 61215 series of standards is here proposed as a minimum requirement. Although the test sequences can be relatively expensive and require several months for completion (see Annex A), they are already considered as a market-entry requirement by major manufacturers. As the EN IEC 61215 test sequences consider the major stressors, including their combination, to which PV modules would be subjected in the field, they cannot be split without loss of reliability. Other aspects (such as encapsulant browning or inspections for cell cracking) are the subject of quality standards at PV modules' component level[5]. Customers in the market segments of commercial and utility-scale solar PV systems request PV modules to successfully pass the EN IEC 61215 requirements. Moreover, all the feed-in tariff schemes that were reviewed as part of the PV preparatory study[6] have requested compliance to the EN IEC 61215 series of standards for residential contracts. As such, the EN IEC 61215 can be considered a de facto entry requirement for the residential market segment in various EU member states.

2.2.1 Quality assurance of the production process

Performance aspect	Detailed proposed requirements
Design qualification for long-term operation (conformity assessment procedure)	For the purposes of requirements set out in [*reference to relevant part of the Annexes]*, the conformity assessment procedure referred to in Article 8 of Directive 2009/125/EC shall be the quality assurance system set out in [*reference to new Annex on conformity assessment*]. SEE ANNEX A Part 2 for further details

TECHNICAL AND-LEGAL CONSIDERATIONS

The proposed ecodesign requirements on durability, set out above and in Annex A Part 1, obliges PV modules to be capable of withstanding prolonged exposure to open-air climates. Given that the PV modules have a designed technical lifetime of around 30 years,

[5] Table 3 of the report JRC111455 "Standards for the assessment of the environmental performance of photovoltaic modules, power conversion equipment and photovoltaic systems", http://dx.doi.org/10.2760/89830

[6] PV preparatory study - Task 8

they have to be able to pass a sequence of tests simulating a range of environmental stressors (e.g. damp heat, hail) that could lead to product failure or decreased performance. To confirm whether a specific product model complies with these durability requirements, Annex A Part 1 proposes a testing method (in line with the EN IEC 61215 series) that involves subjecting 10 modules representative of that product model to the relevant tests (this is also the case for the proposed market surveillance procedure). It is for the manufacturer to ensure and declare that all the individual units of relevant model placed on the market comply with the requirements.

Taken together, this approach in principle provides a good basis for ensuring conformity with the durability requirements. A specificity of PV modules, however, is that deviations from the expected quality of the production process can easily lead to products (i.e. PV modules) with decreased resistance to the environmental stressors that they must be capable of withstanding, and for which the product model is tested. For example, defects in the backsheets of a module may not reveal an initial decrease of performance in standard product tests. However, when installed in the field, such defects can create entry points for the intrusion of water, dust and particles that accelerate the degradation of the PV modules.

The production process for PV modules needs to be carefully managed in order to safeguard the quality. The preparatory study showed that, when mass-produced, a lack of quality control of the production process can, among other things, lead to deviations from the model design, variations in material quality, as well as lapses in the precision manufacturing necessary to achieve the durability performance of the product model. The inspection of the quality of the production process is a quite common practice used by developers buying large volumes of modules. However, such practices are not within reach for regular buyers or consumers.

Therefore, for the durability requirements, it is proposed to enhance the standard conformity assessment modules set out in the Ecodesign Directive by requiring manufacturers to additionally have a third-party verified quality assurance system in place. Article 8(2) of the Ecodesign Directive explicitly foresees the possibility to choose, where duly justified and proportionate to the risk, a conformity assessment procedure from among the standard modules used EU product legislation set out in Decision 768/2008/EC. Module D1, which combines the internal production control system common to Ecodesign measures with a third-party verified quality assurance system, is best suited to take account of the specificities related to the durability of PV modules set out above. This choice is justified by the need to take into account the significance of the quality of the production process in ensuring conformity with the proposed durability requirements for PV modules.

The procedure proposed, of which a sketch is included in Annex A Part 2, would work in synergy with the conformity declaration of the manufacturer, which is based on the testing of 10 modules representative of a product model, by ensuring the quality of the production of the individual units of that model and thereby further safeguard the durability of individual units placed on the EU market. It requires manufacturers to lodge an application for assessment of their quality system with a third-party conformity assessment body (called a ‘notified body’ in EU law), which then performs an assessment, including an on-site audit, to confirm whether it contains all the required elements. The procedure and elements required take inspiration from and aim at an aligned approach with the factory production control instructions set out in IEC EN 62941 (the elements inspired to IEC EN 62941 are in point 5.2 of the suggested procedure, all other points being taken from the basic module and are used widely in EU product legislation). In case of verification, the manufacturers declare conformity with the durability requirements under the responsibility of the relevant notified body (whose identification number is affixed to the products put on the market). The notified bodies then carry out surveillance to make sure the manufacturer duly fulfils the obligations arising out of its approved quality system, including periodic audits and possible unexpected visits.

In line with the approach used in other EU products legislation, it would be for Member State authorities to assess and notify to the Commission which bodies meet the conditions to take up conformity assessment tasks in relation to this requirement. The Commission then publishes a list of available bodies in an existing database. The notification procedure and relevant conditions would be taken from Decision 768/2008/EC, which provides standard provisions in this regard for all EU product legislation.

Lastly, the proposed procedure is considered proportionate as the third party involvement is limited to production process aspects, leaving it to manufacturers to assess the conformity of the product model and of individual products in line with their own processes. This is fitting as the production process is the life cycle stage where non-compliances with the durability requirements could originate that would become apparent only after instalment and (long-term) exposure to open-air climates.

2.3. REQUIREMENT ON PERFORMANCE LONG-TERM DEGRADATION

Performance aspect	**Detailed proposed requirements**
Lifetime performance degradation	The manufacturer shall optionally declare the average linear degradation rate expected over a notional service lifetime of 30 years, following a specific procedure: – *The data should cover at least five consecutive years.* – *The experimental data shall cover all the climatic profiles that are considered in the calculation of the annual energy yield of PV modules.* – *The data shall be collected from at least 2 (two) separate geographic locations in each climatic zone. It should contain open rack ground-mounted, roof-mounted and building added (at least 3 of the four options must be included).* – *The assigned degradation rate shall be the average of all collected degradation rates from above.* In lack of this information, default degradation values would be applied for the energy labelling calculation

Long-term performance degradation of modules can have a significant impact on life time electricity generation. Claims made by manufacturers for their products' degradation rate or, linked this, the power guarantee, currently don't have a standardised basis and are not usually backed up by an explanation of the method by which they have been derived. A transitional method (given in the previous table) has therefore been developed by the JRC, specifying the need for claims to be based on field observations over a minimum period of time.

2.4. Requirement on Repairability

Performance aspect	Detailed proposed requirements
Repairability	The manufacturer shall report on: – the possibility to access and replace the bypass diodes in the junction box, – the possibility to replace the whole junction box of the module.

These information requirements would be aimed to ensure that modules can be disassembled in order to facilitate repairing. Although the failure rate for modules installed was reported in the preparatory study to be low, at around 0.5%, the junction box and bypass diodes were identified as a point of attention for ease of repair. There is a trend observed in major manufacturers products in 2020 towards soldered instead of plug-in diodes which may prevent replacement. Moreover, the junction boxes are filled in polymer resin to provide the sealing of the junction box in order to improve the ingress protection (IP) rating. In the case of access and diode replacement being hindered it should be at least possible to replace the whole junction box without damaging the integrity of the PV module and the backsheet.

2.5. Requirement on Recyclability

Performance aspect	Detailed proposed requirements
Dismantlability	The manufacturers shall report on the potential to separate and recover the semi-conductor from the frame, glass, encapsulants and backsheet. Design measures to prevent breakage and enable a clean separation of the glass, contacts and internal layers during the operations shall be detailed.
Material disclosure	The manufacturer shall declare the content in grams of the following critical raw materials and environmentally relevant materials in the PV modules or any product part: – Lead

	− Cadmium − Silicon metal − Silver − Indium − Gallium − Tellurium − Metal solder and contacts − Glass fining agents − Phthalates in power cables For the encapsulant and backsheet the manufacturer shall also declare as well as the content in grams, the type of polymers used, including whether it is fluorinated or contains fluorinated additives.

In the preparatory study it was found that the design for recycling is related with the fact that the components and their means of assembly allow for an easier separation, including ease of access to the cells without breakage. Materials should then be carefully selected in order to allow for recycling. In the case of current module designs, which are more problematic to achieve a clean separation of materials, materials choices may hinder recovery processes.

A two-fold effect of this requirement is therefore expected. First to promote design for recycling. Second, to facilitate future end of life recovery of valuable raw materials and to identify appropriate recovery routes. For example, in the case of encapsulant and backsheet materials, where the presence of fluorinated materials could create a processing hazard.

2.6. Requirement on Ecological Profile

Performance aspect	**Detailed proposed requirements**
Ecological profile	As of *[XX months after the entry into force of the implementing regulation*], the following information requirements would apply to PV modules: at least for each product model, a declaration of the 'ecological profile'[7] (notably on the carbon footprint and, possibly, of the primary energy consumption) drawn up in accordance with the harmonised calculation rules set out in [*reference to relevant part of the implementing regulation]*. *An outline of the harmonised calculation rules in relation to the ecological profile of PV modules can be found in Annex B.*

This ecodesign information requirement would establish a standardised basis for the collection, analysis and presentation of (certain relevant aspects of) the ecological profile

[7] Under the meaning of article 2(20) of the Ecodesign Directive 2009/125/EC

of PV modules. It would be based on a Life Cycle Assessment (LCA) approach, with a focus on:

- Global Warming Potential (GWP). This category is often referred to as the carbon footprint or the embodied emissions.
- *As a possibility*: Energy consumption during the relevant life cycle stages, communicated per primary energy source and separately accounting for renewable energy use in the production process.

This requirement would represent a first step in establishing a consistent basis for comparing the environmental performance of the products. The industrial stakeholders that have been so far contributing to the Ecodesign/Energy Labelling preparation consider this aspect as highly relevant[8]. Moreover, certain national jurisdictions at EU level – notably France, Italy and Spain – have been recently introducing public procurement schemes for PV modules making use, inter alia, of information – and even quantitative – requirements on the products' environmental footprint / ecological profile (see also the Table in Annex C). The proposed requirement would provide a harmonised format for providing the relevant information.

In line with the findings of the preparatory study, the ecological profile assessment should focus solely on impacts occurring during the raw material selection and manufacturing phase[9]. In fact, it clearly emerges from the analysis of the impacts that the bulk of energy use and greenhouse gas emission takes place during these phases. The most energy- and carbon-intensive part of the life cycle of silicon-based technologies is the production of photovoltaic cells. For example, for monocrystalline PV cells, reported emissions during the production phase account for 93.7% of total GHG emissions[10]. For all technologies included in the Product Environmental Footprint Category Rules (PEFCR) on photovoltaic modules, climate change was also a significant impact, for a large part driven by the raw material acquisition and pre-processing stages[11]. The legal framework also specifically foresees this approach, as discussed in the next subsection.

It should also be noted that the proposed requirement is part of a wider set of ecodesign requirements (i.e. all the others described in the present discussion paper) addressing the most relevant impacts of PV modules and covering all life cycle stages. The proposed requirements on, for example, efficiency, durability, and reparability are aimed at limiting the overall environmental impact of PV modules, acting on life cycle stages of the product different than those targeted by the requirement described in this section (i.e. raw material selection and manufacturing phase). Therefore, the proposed requirement on the ecological profile is meant to act independently – and in synergy – with the other requirements.

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[8] See for example 'EXPERT INPUT PAPER – ECO-DESIGN & ENERGY LABELLING FOR PHOTOVOLTAIC MODULES,
INVERTERS AND SYSTEMS IN THE EU', available at https://etip-pv.eu/publications/etip-pv-publications/

[9] See the subsection on legal aspects for an explanation about 'raw material selection'

[10] Tawalbeh M., et al, A critical review of impacts of solar photovoltaic systems recent progress and future outlook, Science of the Total Environment Environmental 759(2021)143528

[11] Technologies covered were cadmium telluride, copper-indium-gallium-selenide, micromorphous silicon, multicrystalline silicon and monocrystalline silicon PV modules. The PEFCR is available at the link https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_PV_electricity_feb2020_2.pdf

LEGAL ASPECTS

The Ecodesign Directive 2009/125/EC provides all tools necessary to operationalise the proposed requirement and adapt it to the specificities of PV modules. Importantly, it provides a clear legal basis for requiring the calculation and publication of environmental performance information. Annex I Part 3 lists as a possible manufacturer obligation the establishment of a product's ecological profile. The Directive defines such a profile as 'a description, in accordance with the implementing measure applicable to the product, of the inputs and outputs (such as material, emissions and waste) associated with a product throughout its life cycle which are significant from the point of view of its environmental impact and are expressed in physical quantities that can be measured.'

In line with this definition and the method set out in Annex I, the implementing measure should specify how to draw up the ecological profile in relation to the relevant product. In particular, it should identify the significant impacts and their related inputs and outputs. To structure this task, Annex I Part 1 provides a list of life-cycle stages, environmental aspects and their related parameters to be selected as is appropriate to the relevant product. In line with the previous subsection, global warming potential is currently the most important impact category. Along with life-cycle energy consumption, it is considered a reliable indicator of products' environmental performance. These elements are therefore considered the most appropriate parameters for expressing the ecological profile of PV modules.

The ecological profile assessment would focus solely on impacts occurring during the raw material selection and manufacturing phase[12]. On top of the technical reasons discussed in the previous subsection, it should be noted that ecodesign requirements currently affect manufacturers at the moment of the placing on the market of their products. Therefore, the reporting obligation should ideally target the phases and processes under their direct control in legal terms. Expanding the scope of the analysis to life cycle stages after the manufacturing phase, namely the use phase and the end-of-life phase, is conceptually feasible; however, this would rely, in practical terms, on a range of assumptions about the impacts of life cycle stages that are outside the legal responsibility of the manufacturer (i.e. outside the obligations stemming from an Ecodesign Implementing Regulation, that affect products at the moment of their placing on the market). In addition, gathering robust and representative data on these life cycle stages would be overly cumbersome for the manufacturer and, as explained above, aspects related to the end-of-life would be addressed through other specific eco-design requirements.

The obligation to publish the resulting information in order to ensure its availability for the relevant actors could then be based on Article 14(b) or Annex I Part 2(b) of the Ecodesign Directive. The intention would be to offer installers and consumers – as well as procuring parties - a reliable and verifiable measure of the ecological profile of PV modules. The final value to be published would depend on the functional unit chosen as a basis for the ecological profile assessment. For example, the declaration would indicate the amount of kilograms of CO_2 equivalent (the unit of measurement for GWP) emitted per kWh of energy produced.

[12] The names of these life cycle stages are in line with the wording of Annex I part 1 of the Ecodesign Directive. They are related to the raw material acquisition, pre-processing and production.

PROPOSED METHODOLOGY & TOOL

To strive for maximum comparability of the published values, the implementing measure should provide a single method for drawing up the ecological profile. It should therefore contain clear harmonised rules and assumptions for modelling and calculation. In this regard, it would not suffice to rely on general rules for conducting an LCA (such as ISO 14040) or even more specific rules applicable to a range of products (such as ISO 14067 or EN 15804), as these rules would allow for diverging modelling and assumptions. Rather, such rules should provide more detail and need to be specific solely to PV modules. Annex C gives an overview of standards, documents and guidelines that are related (with a different degree of granularity) to the calculation of the carbon footprint of PV products.

Given that, in the specific case of PV modules, environmental category rules have been established by the EU Commission in dedicated Product Environmental Footprint Category Rules (PEFCRs)[18], it is proposed to follow this methodology to the extent possible for the ecological footprint of PV modules.

The relevant part of the implementing measure could therefore be modelled taking inspiration from the rules outlined in Annex II of the proposal for the Batteries Regulation[13], which contains carbon footprint calculation rules specific to batteries, also based on the relevant PEFCR. A sketch of the possible harmonised calculation rules for PV modules is provided in Annex B of this document. The relevant rules should pay particular attention to the modelling and data requirements related to energy use during the production process. Particular attention should be paid to the possible use of a company-specific electricity mix, including whether and how renewable energy certificates (such as European Energy Certification or similar schemes) can be used to determine this electricity mix.

For what concerns the tool in support to the ecological profile declaration, the suggested approach consists in the use of an adapted/tailored version of the EcoReport tool[14]. This tool would be specifically tailored to comply with the single harmonised calculation method set out in the implementing measure.[15] Alignment with the PEFCR should be sought as much as possible (for example datasets and primary data to be collected, as specified in the PEFCR), with some simplifications (e.g. considering only some life cycle stages, etc.) to adapt to the aim of the proposed requirement.

The envisaged tool would consist of an input sheet resembling a bill of materials tailored to the relevant products, allowing manufacturers to input the materials and amounts applicable to their products. This sheet would then be linked to harmonised secondary datasets providing default input and output values in relation to the relevant materials and processes. Such a tool would allow manufacturers to obtain the necessary values simply by putting in information on certain basic characteristics of their products, i.e. their

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[13] See COM(2020)798, the relevant document can be downloaded here: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12399-Modernising-the-EU-s-batteries-legislation.

14 The Ecoreport tool is used extensively in the context of Ecodesign preparatory studies (i.e. within the MEErP). The Ecoreport tool is being improved/updated in the ongoing review study of the MEErP. Inter alia, updated environmental datasets will be introduced. The adapted version of the Ecoreport tool hereby referred would be used only for the calculation of the PV module ecological footprint, keeping the ‘standard’ Ecoreport tool for studies conducted under the MEErP (i.e. Ecodesign preparatory and review studies).

15 The Commission intends to offer a similar tool in relation to the carbon footprint requirement included in the recent Batteries Proposal, see page 219 of the impact assessment, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2020%3A335%3AFIN.

material composition and the relevant production process specific to their products. Via the tool, the manufacturer would also need to upload company-specific data at least where required by the harmonised calculation rules. In addition, the tool would allow manufacturers to input company-specific data for other processes where it so prefers.

The benefits deriving from the use of this tool are further described in the ‘Conformity assessment considerations’ subsection.

SYNERGY WITH THE PRODUCT ENVIRONMENTAL FOOTPRINT METHOD (AND RELATED INITIATIVES)

The information requirement on the ecological profile would be in line with the political commitment towards the reduction of carbon and environmental footprints. It would also constitute a novelty in terms of regulatory approaches under the current Ecodesign Directive. At European Commission level there are two ongoing initiatives[16] aimed at exploring the feasibility of requirements concerning the environmental footprint of products; implementing measures within the framework of these initiatives could be expected in the medium term.

Within this policy scenario, the current proposal for an ecological profile requirement under the current Ecodesign Directive would represent[17] a regulatory solution targeted to specific products (PV modules) and policy commitments (the reduction of PV modules environmental impact), that could be enacted in the short term, without prejudice to the outcomes of the two ongoing Commission initiatives[16] on the environmental footprint of products, that are much broader in terms of scope and impact coverage.

In methodological terms (see previous subsection), the reference methodology proposed in support for the ecological profile requirement is the one laid down in the Product Environmental Footprint Category Rules (PEFCR) of ‘Photovoltaic modules used in photovoltaic power systems for electricity generation’[18], in particular concerning:

- the underlying environmental datasets;
- the impact categories: global warming potential and cumulative energy demand
- the interested life cycle stages, and the related most relevant processes

[16] See ‘Environmental performance of products & businesses – substantiating claims’ at https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12511-Environmental-claims-based-on-environmental-footprint-methods and ‘Sustainable Products Initiative’ at https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12567-Sustainable-Products-Initiative

[17] With a conceptually similar approach to the Batteries Regulation proposal

[18] https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_PV_electricity_feb2020_2.pdf

CONFORMITY ASSESSMENT CONSIDERATIONS

Performance aspect	Detailed proposed requirements
Ecological profile (conformity assessment procedure)	For the purposes of requirements set out in [*reference to relevant part of the Annexes]*, the conformity assessment procedure referred to in Article 8 of Directive 2009/125/EC shall be the procedure set out in [*reference to new Annex on conformity assessment*]. SEE Annex B Part 2 for further details

In order to effectively operationalise the proposed requirement, the implementing measure should include conformity assessment and market surveillance provisions adapted to the specificities of the calculation and publication of ecological profile information. As sketched out in Annex B Part 2, it is proposed to take as a basis the commonly used internal production control system, adding to it the third-party verification of the reliability of the calculation and the underlying data. It is in line with the approach taken in relation to the carbon footprint requirement included in the recent proposal for a Batteries Regulation[19].

Article 8(2) of the Ecodesign Directive expressly allows implementing measures to, where justified, specify a procedure different from those set out in its Annexes and to have recourse to one of the other conformity assessment procedures used in other EU product legislation.[20] The default approach taken in existing implementing measures is based on the assumption that market surveillance authorities can verify compliance with the applicable requirements directly on the product, i.e. by testing individual products. As the envisaged requirement on the ecological profile relates to impacts occurring during the production process, verification of compliance would have to be based primarily on the technical documentation related to the relevant calculations rather than on product testing.[21] It is then imperative to ensure that such documentation is reliable and complete.

These challenges can be addressed by requiring third party conformity assessment of the reliability of the ecological profile calculations, which would take place before the placing on the market. The proposed procedure is tailored to the requirement, and would require an independent third party[22] to verify whether the ecological profile assessment was performed in line with the rules laid down in the implementing measure and whether the company-specific data used is reliable. In line with the approach used in other EU products legislation, it would be for Member State authorities to assess and notify to the Commission which bodies meet the conditions to take up conformity assessment tasks in relation to this requirement. The Commission then publishes a list of available bodies in an existing database. The rules setting out the notification procedure and relevant

[19] See Article 17 and Annex VIII Part B.

[20] See the list of conformity assessment modules included in Annex II to Decision 768/2008/EC – the procedure proposed here is based on Module A1 set out in Annex II of the Decision.

[21] In addition to conformity assessment, the implementing measure would therefore need to include specific rules on the market surveillance procedure in relation to the ecological profile declaration.

[22] Referred to as a 'notified body' in EU product legislation.

conditions would be taken from Decision 768/2008/EC, which provides standard provisions in this regard for all EU product legislation (one set of rules would cover both this requirement and the one on durability, where notified bodies are also proposed to be involved).

In addition to minimizing the administrative burden, the mandatory use of a freely accessible calculation tool – in line with the features described in the 'Proposed methodology & tool' subsection - would also facilitate market surveillance and conformity assessment. It would automatically apply many of the harmonised calculation rules, compliance with those rules is guaranteed by using it, allowing market surveillance and conformity assessment to focus on checking the validity of the information put into the tool and the reliability of the company-specific data uploaded. The validity of the information put into the information sheet would be verified by checking the relevant technical documentation and examining representative specimens of the product. Where company- or supplier-specific data is uploaded, verification of the reliability of that data would, in addition to a documentary check, include an on-site audit of the production site(s) that the data represents.

In order to further minimise the administrative burden linked to the proposed requirement, manufacturers placing on the market PV modules could be allowed to rely on verified company-specific data concerning components/subassemblies or materials coming from suppliers. The implementing measure should provide conditions for the third party verification of relevant data from suppliers, in turn allowing manufacturers to rely on such verified data when calculating the ecological profile. This has the potential to greatly reduce the primary data to be verified during the conformity assessment procedure of an individual PV module.

3. ECODESIGN REQUIREMENTS FOR PV INVERTERS

The following requirements are proposed to be set that would apply to inverters placed on the EU market and intended for use in photovoltaic systems for grid-connected electricity generation.

Inverters excluded from the scope of this study are:

- Central inverters that are packaged with transformers (sometimes referred to as central solutions) as defined in Commission Regulation (EU) No 548/2014 on Ecodesign requirements for small, medium and large power transformers.

3.1. REQUIREMENTS ON EFFICIENCY

Performance aspect	**Detailed proposed requirements**
Euro Efficiency minimum requirement for PV inverters without storage	Overall efficiency of grid connected PV inverters. Require a minimum Euro efficiency at Tier 1 of 94% and Tier 2 at 96% measured according to EN 50530:2010/A1:2013. *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 for each of the partial MPP power levels used in formula D.1 for the calculation on the Euroefficiency. - Efficiency dependency on inverter's temperature. Detailed tabulated for temperature derating information should be provided. (EN 50524:2009 will be superseded by prEN50524)
Efficiency requirements for PV inverters with 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 'Effizienzleitfaden 2.0'. The efficiency value corresponds to performance with a fully charged battery.

The proposed requirement is based on the EN 50350 method for calculating the 'Euro Efficiency' of an inverter. This is an important derating factor for the performance of a solar PV system, so the removal of the worst performing, sub 94% efficient inverters would contribute as a minimum requirement for the inverter derating factor. It is also considered important to request improved and more consistent additional information in the form of tabulated efficiency values and the inverter's temperature dependency.

The increasing role in the future of hybrid inverters incorporating battery storage introduces the possibility that such efficiency gains could be reversed in order to raise self-consumption so it is also considered important to have complementary requirements on the efficiency of hybrid systems. This would entail reference to the private German Effizienzleitfaden standard, which may shortly be developed into a national DIN (Deutsches Institut für Normung) standard.

3.2. Requirement on Durability

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.

The formulation of Ecodesign requirements for the durability of PV inverters could follow an approach conceptually similar to the one used for PV modules.

The design qualification of inverters according to test sequence set out in IEC 62093 is proposed as a minimum requirement.

IEC 62093 "Balance-of-system components for photovoltaic systems – Design qualification natural environments" establishes the requirements for design qualification for BOS components (like batteries, inverters, charge controllers, etc) of PV systems in operation indoors or outdoors. The standard describes a sequence of tests to determine the performance characteristics of each BOS and to show that each component is capable of maintaining its performance after exposure to the simulated service natural environmental conditions. The test severities depend on the service use which can be classified as indoors (conditioned or unconditioned) or outdoors (protected or unprotected).

Inverters are to be submitted to basic environmental testing (including insulation test, outdoor exposure test, shipping vibration test, thermal cycling test, humidity-freeze test, etc) followed by damp heat and cycling tests as defined in the standard (Figure 1 of the IEC 62093).

Similarly to PV modules, it could be proposed to enhance the standard conformity assessment modules set out in the Ecodesign Directive by requiring manufacturers to additionally have a third-party verified quality assurance system in place. In the case of inverters, the factory quality controls and auditing according to IEC TS 63157 could constitute the reference methodology.

3.3. Requirement on smart readiness

Performance aspect	Detailed proposed requirements
Smart readiness	The inverter shall have physical and/or wireless connectivity and be capable of communicating with other devices using a an open standard data transfer protocol. Communication with distribution networks will be in accordance with EN50549 requirements. Information shall be proved on cybersecurity and demand response management capabilities. All inverters will provide for external monitoring of AC electrical output with a sampling interval of 1 minute or less. Inverters used in PV plants > 40MW shall support class B data monitoring according to IEC 61724-1”

3.4. Requirement on Repairability

Performance aspect	Detailed proposed requirements
Repairability requirements for all size inverters	Manufacturers shall ensure the following requirements about spare parts: 1. all electronic/electromechanical components of the inverter are available for a minimum period of 15 years 2. At least each individual printed circuit board and disconnectable component must be provided as spare part 3. The delivery of spare parts must take place within 15 working days within Europe. 4. Spare parts must be replaced using the tool classes stablished below according to the size.
Repairability requirements for inverters <30 kW	The manufacturer shall identify which of the circuit boards can be replaced on site.

	Manufacturers, importers or authorised representatives of inverters shall meet the following requirements according to EN 45554:2020: 1. Fasteners and connectors: Reusable (Class A) 2. Tools: Feasible with the use of no tool, or a tool or set of tools that is supplied with the product or spare part, or basic tools as listed in Table A.3 of EN 45554 (Class A) 3. Working environment: Use environment (Class A) 4. Skill level: Generalist (Class B)
Repairability requirements for inverters >30 kW	Manufacturers shall provide 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).
	Manufacturers, importers or authorised representatives of inverters shall meet the following disassembly requirements according to EN 45554:2020: 1. Fasteners and connectors: Reusable (Class A) 2. Tools: Feasible with product specific tools (Class B) 3. Working environment: Worskhop environment (Class B) 4. Skill level: Expert (Class C)

The potential to maintain the functionality of the inverter on-site is also considered important in order to minimise the life cycle impacts associated with short replacement cycles. To this end repairability requirements are proposed that seek to inform professionals and consumers about the maintenance and repair potential of the product. The outcome is anticipated to be an improved focus on mid-life wear-out and preventative maintenance in the residential and commercial market segments.

3.5. Requirement on Recyclability

Performance aspect	**Detailed proposed requirements**
Material disclosure	The manufacturer shall declare the content in grams of the following critical raw materials and environmentally relevant materials in the product as a whole and in the replaceable circuit boards: • Lead • Cadmium • Silicon carbide • Silver • Indium • Gallium

	• Tantalum • Metal solder and contacts • Glass fining agents • Phthalates in power cables

As for PV modules, the disclosure of this list of material present in the PV inverters and their subcomponents follows the same reasoning. First to promote design for recycling. Second, this information facilitates future end of life recovery of valuable raw materials and to identify appropriate recovery routes in an environmentally safe manner.

3.6. Requirement on Environmental Footprint

Similarly to PV modules, Ecodesign information requirements on the ecological profile of the manufacturing phase of inverters could be proposed. This part, however, is not dealt within this version of the discussion paper.

4. Energy Labelling for PV modules and systems

In general terms, 'energy efficiency', when related to energy conversion processes, represents the conversion efficiency, such as the ratio of generated end-use energy in proportion to the primary energy. When related to energy-consuming products, the energy efficiency can be regarded as the ratio between the product performance, provided that it is possible to quantify it, and the energy used to obtain it, such as the light emitted by a light bulb for a given amount of energy. In line with this rationale is the definition of 'energy efficiency' within the Energy Labelling Regulation 2017/1369: 'the ratio of output of performance, service, goods or energy to input of energy'. So far, this approach has been successfully applied to a wide range of energy using products from both the business-to-consumer and the business-to-business sectors, such as washing machines, dishwashers, household, commercial and professional refrigerators, ventilation units, etc.

When applying the same approach to PV modules and systems, a change of perspective is needed, as we are dealing with energy-generating products rather than energy-consuming ones. In line with the concept outlined above, the 'energy efficiency' of energy-generating products can be conceptually conceived to be the ratio of the generated energy available for the final application to the incoming energy (i.e. the amount of solar radiation reaching the surface area covered by the relevant system or module). As such, we can give the following definitions:

- an energy label for PV modules could be based on the module's energy-efficiency index (EEI), defined as the ratio between the annual energy yield that is used to calculate the CSER[23] value and the area of the PV module;
- an energy label for PV systems, i.e. installations, would be similarly the ratio between the lifetime energy yield of the system and the area covered by the PV system.

[23] CSER is defined in ENI EC 61853-3 and relates the received solar energy to the electrical energy output under specific climatic and installation conditions tabulated in ENI EC 61853-4

The energy label would contain one ranking value for each of the three reference climatic profiles representative of Europe.
The energy labels proposed in this section are meant to act as tools enabling installers as well as non-professional purchasers to make informed choices based on the energy efficiency of the products/systems.
For the legal aspects of introducing energy labelling for PV modules and systems, see Annex D.
The potential thresholds of the label classes for both energy labelling of PV modules and systems are presented in Annex E.

4.1. ENERGY LABEL FOR PV MODULES

Performance aspect	**Proposed energy labelling scheme**
DC module energy yield	Module DC energy output for year zero (excluding degradation) calculated according to EN IEC 61853-3, for the three climate zones defined in EN IEC 61853-4 that best represent the European climatic conditions (Subtropical arid, Temperate continental and Temperate coastal) shall be declared by the manufacturer expressed in kWh/m^2. *Modules with inseparable AC integrated inverters are not considered here.*

The energy label for PV modules would aim to give information on the energy yield of the module, allowing on the one side installers and designers, and on the other side private individuals considering investment in PV systems, to have immediate and comparable information on the product performance and to be easily able to use this in a purchasing decision.
The series of standards EN 61853 defines a methodology to estimate the DC energy yield delivered by a PV module over one year under predefined inclination, orientation and PV-relevant climatic conditions. For the latter, only the profiles representative of the climatic conditions of the European continent ("Subtropical arid", "Temperate continental" and "Temperate coastal") are selected from the full set of six climatic conditions tabulated in EN IEC 61853-4. The energy-rating model given in the standard EN IEC 61853-3 assumes no degradation for the PV modules. The DC energy yield is estimated hour by hour taking into account the received irradiance and its spectral content, as well as the temperature reached by the PV module, which depends on the irradiance on the plane of the module's front surface (i.e. in-plane irradiance), on the ambient temperature and on the wind speed. The annual DC energy yield expressed in kWh, related with the dimensionless Climate Specific Energy Rating (CSER) parameter defined in EN IEC 61853-3, can be used to define the energy label for PV modules, which will be then normalised per module area.
For bifacial modules, compared to monofacial devices, energy yield is enhanced by the received irradiance on the rear side. Therefore, transitional methods are to be defined to model the said rear-side irradiance. However, the energy label of bifacial modules will be based, as for monofacials, on the energy yield generated over one year under real working conditions, divided by the module area.

4.2. Energy Label for small sized PV systems

Performance aspect	Proposed energy labelling scheme
PV system AC lifetime energy yield	PV system AC energy output generated over an expected operational lifetime of 30 years, estimated considering degradation, efficiency and losses from the different components, losses derived from the installation and configuration of the system (surrounding obstacles, non-optimal configuration, etc.) calculated for the three climate zones defined in EN IEC 61853-4 that best represent the European climatic conditions (Subtropical arid, Temperate continental and Temperate coastal). The AC lifetime energy yield can be estimated by the methodology defined in the transitional method described in JRC114099, doi:10.2760/496002.

The energy label for small PV system installations with installed peak power less than or equal to 20 KWp, e.g. residential buildings, small commercial or mixed residential /commercial buildings, etc. could give information on the expected energy yield delivered by the installation over its lifetime.
This would allow on the one hand installers and designers, and on the other hand private individuals considering investment in PV systems, to have immediate and comparable information on the product's expected performance and to be easily able to use this in a purchasing decision. Installers and designers would in turn be free to develop designs and packages of system components that can improve the energy yield, and therefore the label rating of systems.
From a technical perspective, evidence from selected Member States suggests that the distribution curve of normalised energy yields and performance ratios for the system stock has the potential to be shifted positively upwards through a combination of:

- better design to take into account site-specific conditions,
- learning applied to installation practices,
- reduced losses due to equipment, cabling and maintenance practices.

In this respect, both the repowering of old systems[24] and the optimisation of new system has the potential to contribute.

The EN IEC 61853-3 provides a methodology to estimate the DC energy yield of PV modules that can be used to rate and compare different PV devices and technologies under the same reference operational conditions. However, there is not an equivalent standard for PV systems, yet. In fact, factors such as the degradation of PV modules and other components of the PV system (like inverters, for example), the operational lifetime of PV systems and the expected long-term performance of PV systems and their components under real operational conditions are still the subject of debate and scientific investigation. Often, no distinction is made between long-term degradation of PV modules and PV systems, but they are considered altogether in the scientific literature. Therefore, a transitional method was developed to define these concepts[25] on the basis of validated scientific evidence. The proposed methodology to estimate the PV system's lifetime AC energy yield simulates the performance of the principal components of the PV system (i.e.

[24] Not necessarily covered in the scope of Ecodesign/Energy Labelling
[25] JRC114099, doi:10.2760/496002

the PV modules' array and the inverter) while also taking into account their efficiency losses and their degradation under the reference operational conditions as defined in EN IEC 61853-4. Besides, the impact of the installation (i.e. orientation and inclination of the PV array, presence of nearby obstacles), and the configuration of the PV system are also considered in the estimation of the PV system's lifetime performance. The energy label of PV systems is based on this lifetime AC energy yield, normalized by the installed power of the system and by the area per kWp, and as such it is ultimately expressed in kWh/m^2.

Part 1 - REQUIREMENTS ON DURABILITY

SUBSECTION WITHIN ANNEX II Ecodesign Regulation

Design qualification for long-term operation

From XX YY 20ZZ, manufacturers, importers or authorised representatives shall ensure that PV modules are capable to withstand prolonged exposure in open-air climates, in line with the following functional requirements and with the testing sequence specified in Annex III (meas and calc):

- Insulation
- Ability of the PV module to withstand exposure to outdoor conditions
- Ability of the PV module to withstand hot-spot heating effects
- Ability of the PV module to withstand thermal mismatch, fatigue and other stresses caused by repeated changes of temperature
- Ability of the PV module to withstand the effects of high temperature and humidity followed by sub-zero temperature
- Ability of the PV module to withstand the effects of long-term penetration of humidity
- Robustness of termination
- Insulation under wet operating conditions
- Ability of the module to withstand a minimum static load
- Ability of the PV module to withstand the impact of hail
- Adequacy of the thermal design and relative long-term reliability of the bypass diodes

SUBSECTION WITHIN ANNEX III Ecodesign Regulation

Measurements of the ability of the PV module to withstand prolonged exposure in open-air climates shall be carried out in line with the following testing sequence:

(if needed) Figure adapted from Figure 1 of EN IEC 61215-1

ANNEX IIIa

Parameter	Source	Reference Test Method	Notes
Ability of the module to withstand prolonged exposure in open-air climates	CENELEC	EN IEC 61215-1	

Part 2 – CONFORMITY ASSESSMENT FOR DURABIITY REQUIREMENTS

Disclaimer: the text below is a preliminary sketch of how conformity assessment in relation to the durability requirements might be organised (based on IEC TS 62914). As such, it is subject to further elaboration and specification.

MODULE D1 – QUALITY ASSURANCE OF THE PRODUCTION PROCESS

1. Description of the module

   Quality assurance of the production process is the conformity assessment procedure whereby the manufacturer fulfils the obligations laid down in points 2, 3, 4, 5, 7 and 8, and ensures and declares on his sole responsibility that the products concerned satisfy the requirements set out in [*reference to the relevant part(s) of the Annexes]*.

2. Technical documentation

   The manufacturer shall establish the technical documentation. The documentation may be integrated with the technical documentation drawn up in accordance with other applicable conformity assessment procedures.

   The documentation shall make it possible to assess the product's conformity with the requirements referred to in point 1, and shall include an adequate analysis and assessment of the risk(s). The technical documentation shall specify the applicable requirements referred to in point 1 and cover, as far as relevant for the assessment, the design, manufacture and operation of the product. The technical documentation shall, wherever applicable, contain at least the following elements:

   — a general description of the product and of its intended use,

   — conceptual design and manufacturing drawings and schemes of components, sub-assemblies, circuits, etc.,

   — descriptions and explanations necessary for the understanding of those drawings and schemes and the operation of the product,

   — a list of the harmonised standards and/or other relevant technical specifications the references of which have been published in the *Official Journal of the European Union*, applied in full or in part, and descriptions of the solutions adopted to meet the essential requirements of the legislative instrument where those harmonised standards have not been applied. In the event of partly applied harmonised standards, the technical documentation shall specify the parts which have been applied,

   — results of design calculations made, examinations carried out, etc., and

   — test reports.

3. The manufacturer shall keep the technical documentation at the disposal of the relevant national authorities for 10 years after the product has been placed on the market.

4. Manufacturing

The manufacturer shall operate an approved quality system for production, final product inspection and testing of the products concerned as specified in point 5, and shall be subject to surveillance as specified in point 6.

5. Quality system

5.1. The manufacturer shall lodge an application for assessment of his quality system with the notified body of his choice, for the products concerned.

The application shall include:

— the name and address of the manufacturer and, if the application is lodged by the authorised representative, his name and address as well,

— a written declaration that the same application has not been lodged with any other notified body,

— all relevant information for the product category envisaged,

— the documentation concerning the quality system,

— the technical documentation referred to in point 2.

5.2. The quality system shall ensure compliance of the products with the requirements referred to in point 1. For that purpose, it shall at least:

- include and ensure implementation of a control plan and process flow diagram

- ensure that a control plan and process flow diagram are implemented, including adherence to pre-determined measurement techniques, sampling plans, acceptance criteria, preventive maintenance, and reaction plans for when acceptance criteria are not met.

- determine methods to monitor the performance and accuracy of the equipment used;

- create definitions of product problems and determine rules and processes to minimize their impact;

- include the monitoring of the achievement of the required product quality and conformity to the requirements of the product specification;

- include a change management system for materials and processes and ensure all changes impacting form, fit and function adhere to product requirements and defined internal/external qualification and certification requirements;

- provide for the documentation and traceability of changes to the product and impact from those changes for previous and future product deliveries.

- ensure the identification, documentation, and review of the manufacturing process design input requirements, including product design output data and key materials used in manufacturing, targets for productivity, process capability and cost, customers' requirements, if any, and lessons learned from previous developments.

- ensure that the components, sub-assemblies and assemblies that have a safety, performance, or reliability implication on the finished product and that are purchased from or prepared by a supplier, meet the quality plans, in particular by:

- include evaluation of the quality performance of key materials and audit the supplier of key materials on a regular basis.

- ensure that materials used in the product conform with material specifications

- initiate a specific out of control action plan (OCAP) when a process becomes unstable or not statistically capable. This plan shall include the containment of product and 100 % inspection, as appropriate. A corrective action plan shall then be completed by the organization, indicating specific timing and assigned responsibilities to ensure that the process becomes stable and capable.

- provide for a systematic material review to disposition processes including rework, reuse, and recycle of the nonconforming products and constituent raw materials. Product with unidentified or suspect status shall be identified as potentially nonconforming product and subjected to a systematic review process

- define an ongoing/periodic reliability monitoring/production monitoring program that uses appropriate tests for the known failure mechanisms of the product. The tests shall be conducted on the samples that are selected by the internal sampling procedure. Records of the results of any ongoing/periodic reliability testing/production monitoring

All the elements, requirements and provisions adopted by the manufacturer shall be documented in a systematic and orderly manner in the form of written policies, procedures and instructions. The quality system documentation shall permit a consistent interpretation of the quality programmes, plans, manuals and records.

5.3. The notified body shall assess the quality system to determine whether it satisfies the requirements referred to in point 5.2.

It shall presume conformity with those requirements in respect of the elements of the quality system that comply with the corresponding specifications of the national standard that implements the relevant harmonised standard and/or technical specification.

In addition to experience in quality management systems, the auditing team shall have at least one member with experience of evaluation in the relevant product field and product technology concerned, and knowledge of the applicable requirements of the legislative instrument. The audit shall include an assessment visit to the manufacturer's premises. The auditing team shall review the technical documentation referred to in point 2 in order to verify the manufacturer's ability to identify the relevant requirements of the legislative instrument and to carry out the necessary examinations with a view to ensuring compliance of the product with those requirements.

The decision shall be notified to the manufacturer. The notification shall contain the conclusions of the audit and the reasoned assessment decision.

5.4. The manufacturer shall undertake to fulfil the obligations arising out of the quality system as approved and to maintain it so that it remains adequate and efficient.

5.5. The manufacturer shall keep the notified body that has approved the quality system informed of any intended change to the quality system.

The notified body shall evaluate any proposed changes and decide whether the modified quality system will continue to satisfy the requirements referred to in point 5.2 or whether reassessment is necessary.

It shall notify the manufacturer of its decision. The notification shall contain the conclusions of the examination and the reasoned assessment decision.

6. Surveillance under the responsibility of the notified body

6.1. The purpose of surveillance is to make sure that the manufacturer duly fulfils the obligations arising out of the approved quality system.

6.2. The manufacturer shall, for assessment purposes, allow the notified body access to the manufacture, inspection, testing and storage sites and shall provide it with all necessary information, in particular:

— the quality system documentation,

— the technical documentation referred to in point 2,

— the quality records, such as inspection reports and test data, calibration data, qualification reports on the personnel concerned, etc.

6.3. The notified body shall carry out periodic onsite audits to make sure that the manufacturer maintains and applies the quality system and shall provide the manufacturer with an audit report.

The audits shall at least verify whether:

the material produced is conformal with applicable organization or manufacturer specifications;

the supplier has the capability to deliver the goods on time;

the supplier maintains product quality consistently, notifies and seeks approval when there is any change of products, process, and manufacturing location, or significant process excursion that may affect form, fit, function, reliability, or performance.

the supplier applies methods for incoming inspections and preparation of raw materials.

the supplier establishes control plans for all appropriate processes, sub-assemblies, components, and materials for the final product. Control plans shall:

be based on a risk analysis such as design or process FMEA (failure mode evaluation analysis) outputs, or equivalent.

list the controls used for the manufacturing process control.

6.4. In addition, the notified body may pay unexpected visits to the manufacturer. During such visits the notified body may, if necessary, carry out product tests, or have them carried out, in order to verify that the quality system is functioning correctly. The notified body shall provide the manufacturer with a visit report and, if tests have been carried out, with a test report.

7. Conformity marking and declaration of conformity

7.1. The manufacturer shall affix the required conformity marking set out in the legislative instrument, and, under the responsibility of the notified body referred to in point 5.1, the latter's identification number to each individual product that satisfies the applicable requirements of the legislative instrument.

7.2. The manufacturer shall draw up a written declaration of conformity for each product model and keep it at the disposal of the national authorities for 10 years after the product has been placed on the market. The declaration of conformity shall identify the product model for which it has been drawn up.

A copy of the declaration of conformity shall be made available to the relevant authorities upon request.

8. The manufacturer shall, for a period ending at least 10 years after the product has been placed on the market, keep at the disposal of the national authorities:

— the documentation referred to in point 5.1,

— the change referred to in point 5.5, as approved,

— the decisions and reports of the notified body referred to in points 5.5, 6.3 and 6.4.

9. Each notified body shall inform its notifying authorities of quality system approvals issued or withdrawn, and shall, periodically or upon request, make available to its notifying authorities the list of quality system approvals refused, suspended or otherwise restricted.

Each notified body shall inform the other notified bodies of quality system approvals which it has refused, suspended or withdrawn, and, upon request, of quality system approvals which it has issued.

10. Authorised representative

The manufacturer's obligations set out in points 3, 5.1, 5.5, 7 and 8 may be fulfilled by his authorised representative, on his behalf and under his responsibility, provided that they are specified in the mandate.

Part 3 – TESTING PROCEDURES UNDER EN IEC 61215 SERIES

The main pillar of the qualification of PV modules is the series of standards EN IEC 61215. The current series EN IEC 61215 consists of two main Parts:

1. EN IEC 61215-1 Design qualification and type approval - Part 1: Test requirements, which includes general requirements for testing relevant qualification aspects of PV modules, such as susceptibility to thermal, mechanical and electrical stressors;
2. EN IEC 61215-2 Design qualification and type approval - Part 2: Test procedures, which describes the individual tests to be run in order to qualify a PV module type, i.e. the single materials and components chosen for its manufacturing as well as their layout and interconnection that are part of the specific PV module design.

The new holistic approach given to the series EN IEC 61215 becomes even clearer when the individual material-specific parts in which the EN IEC 61215-1 is split into are considered. Indeed, as listed in the following, they individually address specific requirements for the qualification of PV modules (with higher priority than the general Parts 1 and 2) depending on the active PV material (i.e. the PV technology) that is used in their production:

1. EN 61215-1-1 Design qualification and type approval - Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules;
2. EN 61215-1-2 Design qualification and type approval - Part 1-2: Special requirements for testing of thin-film Cadmium Telluride (CdTe) based photovoltaic (PV) modules;
3. EN 61215-1-3 Design qualification and type approval - Part 1-3: Special requirements for testing of thin-film amorphous silicon based photovoltaic (PV) modules;
4. EN 61215-1-4 Design qualification and type approval - Part 1-4: Special requirements for testing of thin-film Cu(In,Ga)(S,Se)2 based photovoltaic (PV) modules.

The testing required by the EN IEC 61215 series for qualification of PV modules consists of specific sequences of accelerated tests. These aim to simulate, in a much shorter time, the degradation process to which PV modules are likely to be subjected when mounted in real installations and exposed to a foreseeable range of environmental conditions. However, it has to be highlighted that the acceleration factors, which would give a univocal quantitative correspondence between the stressor – as applied in the laboratory – and the degradation achieved in the field because of exposure to specific environmental conditions, are not yet available, because they indeed depend on the climatic conditions to which the PV module is exposed as well as on the specific design and the actual installation of the PV module.
Some accelerated tests are explicitly included in the EN IEC 61215. These are:

a. Thermal cycle test, which considers only temperature as stressor;
b. Damp heat test, which considers the combination of effects due to temperature and humidity. This test is addressed by the individual sub-parts EN IEC 61215-1-X with parameters specific for each PV technology;
c. Humidity freeze test, which aims to causing and revealing possible failures of the sealing materials and components of the PV modules;
d. UV test, which can precondition the polymeric components of the PV module;
e. Static mechanical load test, which simulates the effect of prolonged continuous mechanical loads on the surface of the PV module, such as those caused by constant wind or homogeneous snow accumulation;
f. Hot spot test. It deals with safety issues due to local partial shading on thin-film modules, which can cause the creation of very hot small areas in the PV material and produce failure of the PV module;
g. Hail test.

A total amount of at least 10 modules is required to run the tests included in the series of standards EN IEC 61215. Table A.1 gives the complete list of tests included in EN IEC 61215. It also reports the Module Qualification Test (MQT) code associated to each of them in order to allow easier identification of the test.

Table A.1. Coding of tests included in the series EN IEC 61215.

Test code	**Test Name**	**Reference to other standards for test specifications**[26]
MQT 01	Visual inspection	-
MQT 02	Maximum power determination	EN 60904; EN 60891
MQT 03	Insulation test	-
MQT 04	Measurement of temperature coefficients	EN 60891
MQT 05	Measurement of nominal module operating temperature (NMOT)	EN 61853-2
MQT 06	Performance at STC and NMOT	EN 60904; EN 60891
MQT 07	Performance at low irradiance	EN 60904; EN 60891
MQT 08	Outdoor exposure test	EN 61853-2
MQT 09	Hot-spot endurance test	-
MQT 10	UV preconditioning test	-
MQT 11	Thermal cycling test	-
MQT 12	Humidity-freeze test	-
MQT 13	Damp heat test	EN 60068-2-78
MQT 14	Robustness of terminations	EN 60068-2-21; EN 62790
MQT 15	Wet leakage current test	-
MQT 16	Static mechanical load test	-
MQT 17	Hail test	-
MQT 18	Bypass diode testing	-
MQT 19	Stabilisation	-

[26] This is given as merely informative reference here. The original test procedure and/or requirements may be different from those actually included in the EN IEC 61215 series. The latter must be referenced for the tests coded in this table.

ANNEX B. ECOLOGICAL PROFILE OF PV MODULES

Disclaimer: the text below is a preliminary sketch of how calculation and conformity assessment in relation to the ecological profile requirements might be organised. As such, it is subject to further elaboration and specification.

Part 1 – Harmonised calculation rules

[*The harmonised calculation rules shall build on the latest version of the Commission Product Environmental Footprint*[27] *(PEF) method and relevant Product Environmental Footprint Category Rules (PEFCRs)*[18] *and reflect the international agreements and technical/scientific progress in the area of life cycle assessment*[28]*.]*

1. Definitions

For the purposes of this Annex, the following definitions shall apply:

………….

[*alignment with Annex II.1 of the Battery Regulation*[29]]

2. Scope

This Annex provides harmonised rules on how to calculate the carbon footprint of PV modules.

The calculation of the carbon footprint shall be based on the bill of material, the energy, and auxiliary materials used in a specific plant to produce a specific photovoltaic module model. In particular, the photovoltaic cells, the glass, the frame materials and the electronic components (e.g. junction boxes, cabling) have to be accurately identified, as they may become a relevant contributor for the PV modules carbon footprint.

The calculation shall relate to:

- the PV module model, or
- the PV module model as manufactured in a specific manufacturing plant, or
- a batch [to be further defined] of a PV modules placed on the market.

3. Functional unit and reference flow

The functional unit is further defined as one kWh (kilowatt-hour) of the total energy provided over the service life by the PV modules, measured in kWh DC. The total energy is obtained from the yield calculated according to Annex X.

The reference flow is the amount of product needed to fulfil the defined function and shall be measured in m2 of PV module per kWh of the total energy required by the application

[27] https://eplca.jrc.ec.europa.eu/permalink/PEF_method.pdf
[28] https://ec.europa.eu/environment/eussd/smgp/dev_methods.htm
[29] https://ec.europa.eu/environment/pdf/waste/batteries/Annexes-Proposal_for_a_Regulation_on_batteries_and_waste_batteries.pdf

over its service life. All quantitative input and output data collected by the manufacturer to quantify the carbon footprint shall be calculated in relation to this reference flow.

4. System boundary

The following life cycle stages and processes of the PV modules shall be included in the system boundary:

Life cycle stage	**Short description of the processes included**
Raw material acquisition and pre-processing	Includes mining and pre-processing, up to the manufacturing of silicon ingot, wafers, photovoltaic cells and the supply chain of electric/electronic components and other components such glass, silver, frame and encapsulant materials.
Main product production	Assembly of photovoltaic cells and assembly of modules with the frame (in case) and the electric/electronic components.

The following processes shall be excluded:

- Manufacturing of equipment for modules assembly and recycling, as there is evidence that their impacts can be considered as negligible[30] .

All other processes belonging to the subsequent life cycle stages, such as transport to the place of installation, assembly of the system, use and disposal, dismantling and recycling in its case, of the PV modules, shall be excluded from the lifecycle ecological profile calculations.

5. Use of company specific and secondary datasets

Due to the high number of PV module components or materials and the complexity of the processes, the economic operator may limit the use of company specific data to:

[*List of processes and components for which company-specific data is to be used. Including the most relevant raw materials and production processes in terms of impacts*]

In line the approach chosen, all activity data shall refer to:

- the PV module model, or
- the PV module model as manufactured in a specific manufacturing plant, or
- a batch [*to be further defined]* of a PV modules placed on the market.

If the manufacturer opts for declaring the ecological profile of a product model (with variations across different manufacturing plants) and uses company-specific data, the least favourable values shall be used in the calculation.

[30] https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_PV_electricity_feb2020_2.pdf

A change in the bill of materials or energy mix used to produce a PV module model requires a new calculation of the ecological profile for that PV module model.

[Detailed modelling of the following lifecycle stages:

• Raw material acquisition and pre-processing stage

• Production stage]

6. Ecological profile impact assessment

The ecological profile of the PV modules shall be calculated following the methods available in the tailored version of the Ecoreport tool for PV products for the two impact categories:

- the 'climate change' life cycle impact assessment method expressed in kg of CO2 per kWh produced by the PV product)
- The ´energy embedded´ life cycle impact assessment method expressed in kWh per kWh produced per PV product.

The results shall be provided as characterised results (without normalisation and weighting).

7. Offsets

Offsets are calculated relative to a baseline that represents a hypothetical scenario for what emissions would have been in the absence of the mitigation. Offsets shall not be included in the indicator, but may be reported as an additional indicator.

<u>Part 2 – Conformity assessment procedure</u>

MODULE A1 - INTERNAL PRODUCTION CONTROL PLUS THIRD PARTY VERIFICATION

1. Description of the module

Internal production control plus supervised verification is the conformity assessment procedure whereby the manufacturer fulfils the obligations laid down in points 2, 3, 4, and 5, and ensures and declares that the product satisfy the requirements set out *in [reference to the relevant part of the implementing measure]* that are applicable.

2. Technical documentation

The manufacturer shall draw up the technical documentation. The documentation shall make it possible to assess the product's conformity with the requirements referred to in point 1. The technical documentation shall specify the applicable requirements referred to in point 1 and cover, as far as relevant for the assessment, the design, manufacture and operation of the product. The technical documentation shall contain, wherever applicable, at least the following elements: (a) a general description of the product; (b) conceptual design and manufacturing drawings and schemes of components, subassemblies, circuits; (c) descriptions and explanations necessary for the understanding of the drawings and schemes referred to in point (b) and the operation of the product; and (d) test reports.

3. Manufacturing

The manufacturer that places the product on the Union market shall take all measures necessary so that the manufacturing process and its monitoring ensure compliance of the manufactured products with the technical documentation referred to in point 2 and with the applicable requirements referred to in point 1.

4. Product and information checks

For each:

- product model, or

- product model as manufactured in a specific manufacturing plant, or

- batch that the manufacturer or the importer places on the Union market,

the manufacturer carry out one or more tests on one or more specific aspects of the product model or batch of products in order to verify conformity with the corresponding requirements referred to in point 1. For large product batches, the manufacturer, the authorised representative or the importer shall choose a statistically representative sample of products.

The manufacturer that places the product model on the Union market, shall submit the information and documents referred to in *[reference to the relevant part of the implementing measure]* to the notified body for verification of compliance with the applicable requirements.

5. Verifying reliability of company-specific data

Where the manufacturer makes use of company-specific data in calculating the ecological profile of its products, verification of compliance shall also cover the reliability of this data. The notified body shall verify whether the processes and related inputs and outputs covered by the company-specific data are and remain reliable. The relevant assessment shall include at least the precision, completeness, representativeness, consistency and reproducibility. It shall include an initial onsite audit and subsequent surveillance by the notified body.

Where the data used concern a product model or a product model as produced in a specific manufacturing plant, surveillance shall include periodic audits taking place at least every

6 months to verify that the data used in drawing up the declaration remains representative of the relevant processes.

The manufacturer shall, for assessment purposes, allow the notified body access to the manufacture, inspection, testing and storage sites and shall provide it with all necessary information, in particular:

— the quality system documentation referred to in [*reference to quality system rules related to the durability requirements]*,

— the technical documentation referred to in point 2

- [*to be completed*].

In addition, the notified body shall pay unexpected visits to the manufacturer. During such visits the notified body may, if necessary, carry out tests or measurements, or have them carried out, in order to verify that the company-specific data is reliable. The notified body shall provide the manufacturer with a visit report and, if tests or measurements have been carried out, with a report.

Where the company-specific data concerns processes that are under the responsibility of a supplier, the manufacturer may rely on third-party verification (verifying whether data is in line with the methodology and modelling set out in the harmonised calculation tool*)* of that data performed in line with the rules of this point and organised by the relevant supplier. If so, the manufacturer should ensure that the relevant supplier and notified body continue to comply with the verification and surveillance rules.

6. CE marking and EU declaration of conformity

The manufacturer shall affix the CE marking and, under the responsibility of the notified body referred to in point 4, the latter's identification number to each product, or to the packaging thereof, that satisfies the applicable requirements of this Regulation. If the manufacturer relies on third-party verified supplier data, as provided for in point 4, it shall affix the CE marking also under the responsibility of notified body responsible for that verification and add also its identification number.

The manufacturer shall draw up a an EU declaration of conformity for each product model in accordance with Article 18 and keep it together with the technical documentation at the disposal of the national authorities for ten years after the last product belonging to the respective model has been placed on the market. A copy of the EU declaration of conformity shall be made available to the relevant authorities of Member States upon request.

7. Authorised representative

The manufacturer's obligations set out in point 6 may be fulfilled by the manufacturer's authorised representative, on the manufacturer's behalf and under the manufacturer's responsibility, provided that they are specified in the mandate.

ANNEX C. OVERVIEW OF STANDARDS, DOCUMENTS AND GUIDELINES AS A REFERENCE FOR THE CARBON FOOTPRINT DECLARATION

There are several methodologies, guidance, standards and norms available to perform a greenhouse gas (GHG) accounting – also termed carbon footprint - on PV modules. The general frameworks that can serve as a reference include: the ISO 14067:2018 standard[31] (specifically addressing of products), the GHG protocol product standard[32] and the standard EN 15804[33] framing environmental product declaration (EPD) requirements for construction products. In addition the environmental category rules have been established by the EU Commission in the PEFCR for photovoltaic products[34].

Table. Non exhaustive list of standards, documents and guidelines that can be used as reference for the carbon footprint declaration as a potential Ecodesign mandatory requirement for PV products.

Standards and other guidelines/ reference documents	Description	Method
ISO 14067: 2018	Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification	ISO 14067
GHG Protocol Product Standard	Product Life Cycle Accounting and Reporting Standard to evaluate the full life cycle GHG emissions of a product	GHG Protocol Product Standard
EU Member states PCR (Italy, France, Norway, Finland, Netherlands)	Databases and Product Category Rules for construction products/services where PV modules and inverters are part of new and renovated buildings	EN 15804
European PEFCR for PV modules	Guidance for calculating and reporting products' life cycle environmental impacts	PEF method
Italy's LCA legislation **Promotion of the Green Economy**	Legislation fully based on the Environmental Footprint methods. Voluntary "Made Green in Italy" label	PEF method

[31] ISO Standard 14067: 2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification

[32] GHG Protocol Product Standard - Product Life Cycle Accounting and Reporting Standard. https://ghgprotocol.org/product-standard

[33] EN 15804:2012+A1:2013 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products

[34] Product Environmental Footprint Category Rules (PEFCR)—photovoltaic modules used in photovoltaic power systems for electricity generation, 2019. https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_PV_electricity_v1.1.pdf

NSF/ANSI 457 Sustainability Leadership Standard for PV Modules and PV Inverters	Standard to establish product sustainability performance criteria and corporate performance metrics exemplifying sustainability leadership in the market. Basis of conformity assessment, such as third-party certification.	NSF ANSI 457
France's public tenders for utility scale PV plants	Public tenders include carbon footprint requirements to prioritize projects with low-carbon manufacturing processes1.	ADEME guidelines /ISO14040

The scope of Regulation (EU) 2017/136 setting a framework for energy labelling (hereafter: the Regulation) is defined in its Article 1(1): '*This Regulation lays down a framework that applies to energy-related products […]. It provides for the labelling of those products and the provision of standard product information regarding energy efficiency, the consumption of energy and of other resources by products during use and supplementary information concerning products, thereby enabling customers to choose more efficient products in order to reduce their energy consumption*.' The resulting energy label is then defined as including, as a minimum, a closed scale using the letters A to G, with each letter representing a class of energy savings. The A to G steps of this classification should correspond to significant energy and cost savings and thereby provide appropriate product differentiation from the customer's perspective (see Articles 2(19) and 16(3)(b)).

In order to determine whether PV modules and systems are eligible for energy labelling under the Regulation, it needs to first be established whether they fall within its scope. In addition, it should be established whether it is possible to define classes of energy savings in relation to these products, in line with the definition of the energy label. These conditions are additional to the product-specific criteria set out in Article 16(2), which are partly addressed in Sections 4.1 and 4.2 in relation to modules and systems respectively. The product specific criteria of Article 16(2) will be also scrutinised within the impact assessment report linked with the initiatives on 'Environmental impact of photovoltaics'.

Scope

Although the current set of delegated acts adopted under the Regulation cover only energy using products, its scope as defined above clearly extends to all energy-related products. Article 2(1) defines such energy-related products as any 'good or system with an impact on energy consumption during use.' Both PV systems and modules fit within this definition.

Reinforced by cost-reductions and regulatory developments, PV systems are an increasingly common feature of buildings. As such, PV systems and their component modules have a clear impact on energy consumption during use. Their instalment can significantly lower the consumption of grid electricity by providing a direct source of own electricity to cover part of the relevant building's needs. This is often referred to as self-consumption. An overview of the scientific literature shows that self-consumption, expressed as the share of the PV electricity consumed directly in the building on which a system is installed compared to that system's total production, is normally 30-40%.[35] Readily available technical solutions such as battery storage and demand-side management

[35] See Luthander R., Widén J., Nilsson D., Palm J., *Photovoltaic self-consumption in buildings: A review*, Applied Energy 142, p. 80–94 (2015). More recent studies have found similar or higher values, see for example Talavera, D. L., F. J. Muñoz-Rodriguez, G. Jimenez-Castillo, and C. Rus-Casas., *A new approach to sizing the photovoltaic generator in self-consumption systems based on cost–competitiveness, maximizing direct self-consumption*, Renewable Energy 13, p, 1021-1035 (2019). See also this IEA report from 2016: https://iea-pvps.org/wp-content/uploads/2020/01/IEA-PVPS_-_Self-Consumption_Policies_-_2016_-_2.pdf.

have been shown to increase self-consumption to 60-70%.[36] To give an idea of the impact on energy consumption, a 2018 study of 302 UK households using PV showed that a 45% consumption rate corresponded to a 24% reduction in average annual electricity demand from the grid.[37] Net metering or net-purchasing schemes, in addition, offer a solution for PV electricity that is neither directly used nor stored. Where available, it allows the export of this electricity to be used on the grid, earning the relevant building occupant(s) a certain amount of electricity credits. Such credits can then be used to offset regular grid consumption.

It follows that self-consumption, and where available net metering, of the electricity produced by PV systems and modules lower the consumption of grid electricity. They thereby also lower the utility bills of the occupant(s) of the buildings on which they are installed. In general, it can thus be said that the higher the energy yield of the PV systems and modules installed on a building, the higher the energy savings (i.e. the lower the consumption of grid electricity) as well as the cost savings.

Feasibility of an energy label

Article 1(1) states that the Regulation ‘provides for the […] provision of standard product information regarding energy efficiency […], thereby enabling customers to choose more efficient products in order to reduce their energy consumption.’ This is realised by means of an energy label displaying, at least, a closed scale using the letters A to G, with each letter corresponding class of energy and cost savings. Following the logic set out above, it is possible to define such classes of energy and cost saving based on the energy yield of different PV systems and modules, normalized by the corresponding area of the PV array and module. The higher the energy yield, the higher the savings and therefore the class.

Although the current delegated acts all apply to energy consuming products, the Regulation explicitly foresees that labels can be drawn up also for ‘energy-related products that do not themselves consume energy’ (see recital 10). As set out in Section 4, this explicitly foreseen circumstance requires the label to conceptualize differently energy efficiency and the relevant energy savings. Whereas with energy consuming products, the label’s classes revolve around the ratio between the product performance (e.g. light emitted by a light bulb) and the energy consumed to obtain it, PV systems and modules do not themselves consume energy in the same sense. They rather improve the energy efficiency of buildings in proportion to their energy yield. The classes of the proposed labels therefore reflect different amounts of energy savings resulting from different energy yields. To provide a good basis for consumer differentiation, these yields are normalised per unit area of the system or module surface. In addition, they provide this information for each of the three climatic zones relevant for the EU market, as solar radiation (main climatological variable affecting the PV performance) varies geographically.

[36] Ibid.; Other solutions to boost self-consumption are also implemented at household level, for example the combination of PV systems with heat pumps for summer cooling and winter heating or the direct use of PV for heating of sanitary water.

37 McKenna, Eoghan, Jacquelyn Pless, and Sarah J. Darby., *Solar photovoltaic self-consumption in the UK residential sector: New estimates from a smart grid demonstration project*, Energy Policy 118, p. 482-491 (2018).

Energy yield is here conceptualized as the ratio between the electricity generated by the system or module under realistic operation conditions (in the different climatic zones) and the installed generating power normalised per unit area (expressed as kWp). This is also in line with the Regulation's definition of energy efficiency in Article 2(17) as 'the ratio of output of performance, service, goods or energy to input of energy'. In this case, the amount of generated end-use energy is used as a proxy for the product's performance. In addition, the generating power per unit area is used as a proxy for how much primary energy (i.e. the solar radiation reaching the surface area covered by the relevant modules or system) the module or system utilizes for generation.

As the performance of a PV module or system is an important factor in determining the energy efficiency of the building on which they are installed, the aim of an energy label would be to provide standard product information regarding the energy efficiency improvements resulting from the use of PV modules and systems. In line with the logic of the Regulation, it enables consumers to make an informed purchasing choice based on the performance of PV modules and systems (expressed as their energy yield) offered by retailers and installers, thereby allowing them to optimise the resulting efficiency improvements and reduce their energy consumption.

Additional information on the label

Article 16(3)(c) provides that labels can, where appropriate, include supplementary information, defined as 'information, as specified in a delegated act, on the functional and environmental performance of a product.' It is further specified that such information 'shall be based on data relating to physical product characteristics that are measurable and verifiable by market surveillance authorities.' For the label on PV modules, it would therefore seem possible to include information on the results of the carbon footprint calculation set out in Section 2.6. Namely:

- this information reflects the product's environmental performance;
- the data put into the harmonised carbon footprint calculation tool and verified by the notified bodies relates to the product's physical characteristics (i.e. the kind and amount of materials used);
- these characteristics are able to be measured and verified by market surveillance authorities, either on the basis of the product or on the basis of the accompanying technical documentation.

Lastly, for the label on PV systems, the label could indicate the smart readiness of the system on the basis of Article 16(3)(d), which follows from the ecodesign requirement on inverters in this regard set out in Section 3.3.

ANNEX E – ENERGY LABELLING – POTENTIAL THRESHOLDS

Energy label proposal for PV modules, based on the DC energy yield from one module over the first year of installation, divided by the area of the module, expressed in kWh/m^2, for the three European reference climates.

	Module Energy Efficiency Index (kWh/m^2)		
Energy Label	Subtropical arid	Temperate coastal	Temperate continental
A	> 566	> 257	> 330
B	[566 - 496)	[257 - 226)	[330 - 291)
C	[496 - 426)	[226 - 195)	[291 - 252)
D	[426 - 356)	[195 - 164)	[252 - 213)
E	[356 - 310)	[164 - 140)	[213 - 182)
F	[310 - 265)	[140 - 117)	[182 - 151)
G	≤ 265	≤ 117	≤ 151

	Module Energy Efficiency Index (kWh/m^2)		
Energy Label	Subtropical arid	Temperate coastal	Temperate continental
A	> 566	> 257	> 330
B	[566 - 496)	[257 - 226)	[330 - 291)
C	[496 - 426)	[226 - 195)	[291 - 252)
D	[426 - 356)	[195 - 164)	[252 - 213)
E	[356 - 310)	[164 - 140)	[213 - 182)
F	[310 - 265)	[140 - 117)	[182 - 151)
G	≤ 265	≤ 117	≤ 151

Energy label proposal for PV systems, based on the AC energy yield generated by the PV system over its lifetime divided by the area of the PV array, expressed in kWh/m^2, for the three European reference climates.

	PV System Energy Efficiency Index (kWh/m^2)		
Energy Label	Subtropical arid	Temperate coastal	Temperate continental
A	> 13974	> 6388	> 8232
B	[13974 - 11659)	[6388 - 5343)	[8232 - 6899)
C	[11659 - 9345)	[5343 - 4298)	[6899 - 5566)
D	[9345 - 7031)	[4298 - 3253)	[5566 - 4233)

E	[7031 - 6076)	[3253 - 2766)	[4233 - 3589)
F	[6076 - 5122)	[2766 - 2279)	[3589 - 2946)
G	≤ 5122	≤ 2279	≤ 2946

	PV System Energy Efficiency Index (kWh/m^2)		
Energy Label	Subtropical arid	Temperate coastal	Temperate continental
A	> 13974	> 6388	> 8232
B	[13974 - 11659)	[6388 - 5343)	[8232 - 6899)
C	[11659 - 9345)	[5343 - 4298)	[6899 - 5566)
D	[9345 - 7031)	[4298 - 3253)	[5566 - 4233)
E	[7031 - 6076)	[3253 - 2766)	[4233 - 3589)
F	[6076 - 5122)	[2766 - 2279)	[3589 - 2946)
G	≤ 5122	≤ 2279	≤ 2946