Explanatory memorandum for the Consultation Forum

Ecodesign and energy labelling – Photovoltaic modules, inverters and systems

1. CONTEXT OF THE INITIATIVE

1.1. Grounds for and objectives of the initiative

Ecodesign[1] and Energy Labelling[2] are Single Market rules that make it easier and less costly for business, citizens and governments alike to contribute to the clean energy transition and deliver on the EU's energy efficiency and wider 'European Green Deal' objectives, including the Circular Economy agenda. They create business opportunities and increase resilience by setting harmonised rules for 'energy-related products' on aspects such as energy consumption, water consumption, emission levels and material efficiency, they stimulate both demand for and supply of more sustainable products whilst reducing energy user expenditure significantly: estimates indicate that savings in 2021 exceeded EUR 120 billion and could reach the double in 2022[3]. Furthermore, these policies will help achieve the EU's target of reducing greenhouse gases (GHG) by at least 55% by 2030 (compared to 1990 levels). Ecodesign and energy -labelling policies are also critical to making the EU carbon-neutral by 2050, and central to recent and upcoming legislation, including on:

- achieving 55% of GHG emission reduction by 2030, following the European Commission Communication *'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality*[4];
- increasing the ambition of the renewable-energy targets for 2030, following the review of the Renewable Energy Directive[5];
- promoting efficient use of resources by increasing reparability, recyclability and durability in ecodesign, following the European Green Deal Communication and roadmap of December 2019[6] and the Commission Communication Closing the loop - An EU action plan for the Circular Economy[7] (circular economy action plan);
- REPowerEU Communication[8], which presents a wealth of measures aimed to increase security in the energy supply, through energy savings, diversification of energy supplies, and accelerated roll-out of renewable energy; and
- EU Solar Energy Strategy Communication[9], which includes an EU Solar rooftop Initiative.

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1 Ecodesign Directive 2009/125/EC

2 Energy Labelling Regulation 2017/1369

3 Commission Recommendation (EU) 2021/1749 of 28 September 2021 on Energy Efficiency First: from principles to practice — Guidelines and examples for its implementation in decision-making in the energy sector and beyond (OJ L 350, 4.10.2021, p. 9)

4 *'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality*, COM(2021) 550 final, Brussels, 14.7.2021.

5 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12553-EU-renewable-energy-rules-review_en

6 *The European Green Deal*, COM(2019) 640 final, Brussels, 11.12.2019.

7 *Closing the loop - An EU action plan for the Circular Economy*, COM(2015) 614 final, Brussels, 2.12.2015.

8 https://ec.europa.eu/commission/presscorner/detail/en/ip_22_3131

9 https://energy.ec.europa.eu/communication-eu-solar-strategy-com2022221_en

The 2016-2019 ecodesign working plan envisaged introducing legislation on photovoltaic (PV) modules, inverters and systems under the Ecodesign Directive. In 2017, the Commission launched a preparatory study to explore options for mandatory tools, such as ecodesign and energy-label regulations, and voluntary tools, such as the EU Ecolabel. This resulted in a final report published in December 2020[10]. The study included active stakeholder consultation and three stakeholder meetings (in June 2018, November 2018 and July 2019). The consultation involved over 250 participants, representing a wide range of stakeholders from industry, non-governmental organisations (NGOs) and Member States.

1.2. General context

Solar PV has become the world's fastest-growing energy technology, with demand for solar PV spreading and expanding as it becomes the most competitive option for electricity generation in a growing number of markets and applications. This growth is supported by the decreasing cost of PV systems (EUR/W) and increasingly competitive cost of electricity generated (EUR/MWh).

In 2021, the total installed PV capacity in the EU27 amounted to 165 GW_{AC}[11]. This capacity is projected to grow to around 600GW_{AC}[12] in 2030[13], and above 1 TW in 2050[14]. Given the significant projected growth of PV capacity in the EU and globally, the EU could have a sizeable role in the whole manufacturing value chain.

Given the current market situation for PV products (modules, inverters and systems), there is a need to make it possible to compare claims about: i) modules' energy yield; ii) modules' long-term performance degradation; and iii) life-cycle energy impacts. Moreover, not all products on the market feature good and long-term energy performance.

Moreover, PV systems' energy yield can potentially be increased by: i) improving design, taking into account site-specific conditions, and ii) reducing losses by implementing best practices in selecting proper equipment and coupling it with appropriate cabling and maintenance.

While the utility-scale market is an experienced one, there are strong indications that consumers from the residential and small-scale sector are increasingly interested in considering sustainability when deciding on purchasing PV products. However, the market fails to provide the required transparency in this regard.

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[10] *Preparatory study for solar photovoltaic modules, inverters and systems*, available at https://publications.jrc.ec.europa.eu/repository/handle/JRC122431.

[11] IRENA RE Capacity Statistics 2021: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Apr/IRENA_RE_Capacity_Statistics_2021.pdf.

[12] 'AC' stands for 'alternating' current. When referring to PV installed capacity, it is common to refer to the modules power which is generally given in DC.

[13] See "The EU Solar Energy Strategy " COM (2022)221 final

[14] Average of scenarios of the climate target plan (COM(2020) 562 final), meeting the 55% emission-reduction target.

Lifetime and market development of PV modules and inverters

In 2020, around 18.3 GW[15] were installed in the EU, contributing to a total capacity of 136 GW. Despite the Covid crisis, in 2021 that capacity further increased 21 GW. Overall, PV electricity now represents around 4.5% of total electricity generation.

While PV has established itself as a competitive and reliable technology, it is acknowledged that this relies on high quality manufacturing and appropriate installation and maintenance procedures. Lifetime-limiting factors[16] are product defects related to: i) manufacturing, such as junction-box failures and poor-quality backsheets or encapsulants; ii) installation or transport, such as glass breakage; or iii) operation, due to climatic conditions and ageing.

Manufacturing defects can be minimised by implementing a series of factory quality-testing and inspection routines. Evidence from audit programmes suggests that more stringent factory quality control of materials supplied and manufacturing processes can lead to improvements. It can reduce defects, for example those related to cells (poor handling resulting in cracking), interconnection and tabbing[17] (resulting in misalignment of cells) and material purity (e.g. silver purity). This can in turn reduce the number of rejects and the amount of waste in factories. Feedback from factory inspections suggests that there is currently an overall 1.5% reject rate for all modules.

Moreover, PV modules are manufactured and designed in such a way that it is often difficult to repair and recycle them. In recent years, there has been a trend towards better protection against water and dust ingress in PV modules. However, this came at the expense of reduced reparability. While 10 to 15 years ago, junction boxes where replaceable, the vast majority of PV modules today are designed with integrated junction boxes. These are not meant to be removed or replaced by the user or professional repairer.

Occasionally also the inverter components may fail, namely its main circuit board, AC contactors, fuses, capacitors and fans. Such kind of failures frequently make it necessary to replace the equipment. However, better reparability could lead to more repairs instead of new purchases.

Reparability depends on several factors, such as availability of spare parts, access to broken parts, required tools and work environment, required skills, risk of additional damages resulting from repair operations, availability of repair instructions, access to repair professionals and costs of parts and services.

The objective of the proposed regulations is to ensure that PV modules, inverters and systems available on the European Union market meet the European Union's environmental objectives. The proposed regulations envisage that PV modules and

[15] IRENA RE Capacity Statistics: https://irena.org/Statistics/View-Data-by-Topic/Capacity-and-Generation/Statistics-Time-Series.

[16] Within the preparatory study, a service life of 30 years for PV modules has been identified as the best estimation for the operational lifetime of these products (see at: https://publications.jrc.ec.europa.eu/repository/handle/JRC122431)

[17] Tabbing is the process of applying metal conductive strips (tabs) to the cells to allow the interconnection of the cells in the PV module.

inverters can efficiently fulfil their intended functions while ensuring comparability and minimising manufacturing defects and operational failures, therefore extending replacement cycles.

Energy intensity of PV modules and inverters

The PV modules and inverters that were installed in 2020 (c.a. 18.3 GW) are expected to generate around 643 TWh of green electricity during their lifetime[18]. The electricity consumption for manufacturing these PV modules and inverters is estimated for about 59.5 TWh.[19]

This indicates that an initial energy investment is required before there is a break-even point. A major share of this primary energy is consumed in production sites outside the EU27. Unlike many other energy-related products, the energy consumption of upstream processes to make long-living PV products, such as modules and inverters, is rather high compared to the energy use of the product itself, which produces electricity.

As a part of the EU Solar Strategy[20], by 2030 the total EU solar capacity in EU27 is expected to reach 600 GW which means that over 435 GW[21] still need to be installed. The combined effect of an ecodesign regulation and an energy-labelling regulation that aim primarily for increase of performance, durability and lifetime, may further increase electricity generation of PV panels by 3-5% per year. Additionally, primary-energy savings for PV manufacturing are expected to be up to 25%.

Resource-intensive production

The production of PV modules, inverters and systems is very resource intensive, and life-cycle assessments show that the extraction of materials and the manufacturing processes have the highest impact[22], [23]. Both the type and the processing of materials used for PV modules and inverters are key factors in determining the overall environmental impacts of the devices. For manufacturing, the highest impacts on emissions come from the PV cell for PV modules and from integrated circuits and printed circuit boards for PV inverters. Additional environmental impacts stem from the use of (critical) raw materials in main electronic components.

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[18] With a consideration of the average life time of the PV system of 30 years, and reference parameter of long-term degradation factor of 1% annually.

[19] This figure has been calculated from JRC model of primary energy of the total stock of PV modules and inverters, which amounts for 450000 TJ. A factor of 2.1 for the conversion of Primary Energy to electricity has been used.

[20] Communication from the Commission to the European Parliament, the Council, the European economic and social Committee and the Committee of the Regions; EU Solar Energy Strategy, SWD (2022) 148 final

[21] These figures are provided in alternating current (AC).

[22] *Life Cycle Assessment of Future Photovoltaic Electricity Production from Residential-scale Systems Operated in Europe*, Frischknecht et al, 2015.

[23] *Preparatory study for solar photovoltaic modules, inverters and systems*, Joint Research Centre.

Increasing the yield of PV modules, inverters and systems or prolonging their useful lifetime has a high potential to reduce their overall environmental impact (obviously, together with design and production approaches to decrease the environmental impact of the manufacturing phase). This can be reached by increasing the devices' efficiency, reparability and upgradability[24]. In particular, better reparability could render second use more attractive and boost the market of refurbished devices.

The preparatory study identified a number of areas for potential regulatory action, related to: a) design for reliability (protection from dust and water, longevity); b) the ability of the product to be disassembled and repaired; and c) the provision of appropriate information to users, installers, repairers and recyclers.

End-of-life management

Properly managing PV modules that have reached their end of life could bring environmental benefits of up to 17% for certain environmental-impact categories[10], e.g. human toxicity. In the EU, the PV Cycle programme organises collect of end-of-life modules. However, currently the end of life management of PV modules based on silicon wafer technology, which is the main technology on the market, does not include the recovery of the silicon from the so-called sandwich (backsheet plus cells plus encapsulant, typically ethyl vinyl acetate).

The main manufacturer of cadmium-telluride modules has a programme to take waste modules back to its premises for treatment. According to the company, it recovers up to 90% of materials[25].

PV inverters are very different products and their situation is completely different. They are treated as e-waste.

1.3. Current rules and standards in EU and non-EU countries

The Ecodesign Directive and the product specific regulations made under it are an important instrument for achieving the EU's energy-efficiency targets. Implementing a regulation on PV products would contribute to this process.

At Member State level, France has in place specific carbon-footprint criteria for public tendering of PV modules[26] since January 2019. These criteria aim to select the most sustainable modules in the market by setting a maximum threshold for the carbon footprint. Introducing similar rules is under discussion in Spain. Anticipated inconsistencies

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[24] Upgradability is intended as the ability of the product of having enhanced its functionality, performance, capacity or aesthetics

[25] Cadmium and tellurium separation and refining are carried out by a third party. For pre-2013 sales customers, First Solar, the main manufacturer for this technology, has an unconditional prefunded collection and recycling programme for end-of-life modules. With the sale of each module, First Solar historically set aside sufficient funds to meet the estimated future collection and recycling costs of its modules. Individual modules are labelled with information for the owner on how to return the end-of-life module.

[26] Law N°2020-105: Anti-waste law for a circular economy.

between national rules and EN standards interfere with a common EU approach and require EU-wide rules.

Under Mandate M/543, the European Committee for Standardization (CEN) developed a range of standards addressing material-efficiency aspects, which are partly reflected in the proposed ecodesign regulation. Product-group-specific standards for PV modules and inverters following horizontal standards EN 45550 et seq. need to be developed under a new standardisation mandate. However, some aspects covered by generic standards (such as the classification of tools, working environments and skill levels laid down under EN 45554) also appear to be applicable.

2. LEGAL ASPECTS OF THE INITIATIVE

The draft ecodesign regulation would be a Commission regulation to be adopted pursuant to Article 15 of the Ecodesign Directive. The draft labelling regulation would be a delegated measure to be adopted pursuant to Regulation (EU) 2017/1369 (the 'Energy Labelling Regulation'), in particular Article 16.

Both working documents circulated with this Explanatory memorandum are drafts which have not been adopted or endorsed by the European Commission. Any views expressed, including as to the potential regulatory approach are preliminary views of the Commission services and may not in any circumstances be regarded as stating an official position of the Commission. The information transmitted is intended only for the Member State or entity to which it is addressed for discussions and may contain confidential and/or privileged material.

The legal basis for acting at EU level under the Ecodesign Directive and the Energy Labelling Regulation is Article 114 and Article 194 of the Treaty on the Functioning of the European Union[27]. Article 114 refers to the 'the establishment and functioning of the internal market'. Article 194 gives the EU the objective 'in the context of the establishment and functioning of the internal market and with regard for the need to preserve and improve the environment' to 'ensure security of energy supply in the Union' and 'promote energy efficiency and energy saving and the development of new and renewable forms of energy', among others.

Subsidiarity (for non-exclusive competences)

It is essential to take action at EU level to ensure that the same ecodesign requirements apply to PV products across the internal market, ensuring the free movement of goods within the EU while at the same time contributing to energy efficiency and the circular economy. Adopting ecodesign requirements and/or energy-labelling measures for PV modules, inverters and systems under individual Member States' legislation would create

[27] OJ C 326, 26.10.2012, p. 47.

obstacles to the free movement of goods in the EU. In line with the principle of subsidiarity[28], it is thus appropriate for the measure in question to be adopted at EU level.

<u>Proportionality</u>

Article 16(2) of the Energy Labelling Regulation includes a built-in proportionality and significance test. The article states that delegated acts must specify products that meet the following criteria:

a) the product group must have significant potential for saving energy and, where relevant, other resources;

b) models with equivalent functionality must differ significantly in the relevant performance levels within the product group;

c) there must be no significant negative impact as regards the affordability and the life-cycle cost of the product group; and

d) introducing energy-labelling requirements for a product group must not have a significant negative impact on the functionality of the product during use.

An assessment of the draft proposal in light of these requirements is currently being carried out in the impact assessment. In accordance with the principle of proportionality, this measure does not go beyond what is necessary to achieve the objective, which is to set harmonised ecodesign measures and energy-labelling requirements for PV modules, inverters and systems.

<u>Summary of proposed options for ecodesign and energy-labelling regulations</u>

The two working documents on ecodesign and energy-labelling requirements for PV modules, inverters and systems identify and explain the potential measures described below.

Ecodesign

The scope of the proposed regulation covers PV modules and PV inverters. Some of the ecodesign requirements proposed are 'traditional' ones, affecting either the energy efficiency of PV products (such as the euro-efficiency of inverters) or material-efficiency aspects (such as reparability and recyclability).

The technical analysis of the Joint Research Centre's preparatory study[10] also proposes more innovative regulatory approaches not yet included in existing ecodesign measures, namely to include provisions in relation:

- the carbon footprint of the manufacturing and shipping phase of PV modules; and

[28] The principle of subsidiarity as defined in Article 5 of the Treaty on European Union intends to ensure that decisions are taken as closely as possible to the people. The EU should take action only in areas which fall within its exclusive competence or if action taken at national, regional or local level is not more effective.

- the quality control of the manufacturing process of PV modules and inverters (linked to the conformity assessment procedure).

Given that these regulatory approaches are not included in existing legislation, dedicated analyses on the policy and legal aspects were carried out. On the basis of those analyses, potential regulatory approaches are set out in the proposed Regulations. However, the aim is not to set down a finalised legal formulation, but rather to identify the main aspects which could be further developed.

The proposed ecodesign requirements for increased yield and energy efficiency for PV modules and inverters are set out below.

- Reporting on the energy yield in direct current, expressed in kWh/kWp, and calculated according to the provided methodology.
- Disclosure of the lifetime performance degradation rate (either as a default rate or calculated according to the procedure detailed in the transitional methods).
- Manufacturers must ensure that PV modules and inverters are designed to be reliable, based on standard IEC 61215. These include accelerated tests to demonstrate the product's capability to withstand exposure to outdoor operational conditions.
- The euro-efficiency[29] of PV inverters must be at least 96%, or 90% at 25% of nominal power for hybrid inverters including storage.

The subsection of this explanatory memorandum on resource-intensive production highlighted the relevance of the environmental impacts of the manufacturing phase of PV modules and inverters. In light of this, a set of specific information requirements is proposed for both products.

- Improving reparability increases overall product lifetime and thus material efficiency. This includes requirements on the availability of spare parts, and design for repair (including fasteners, tools, and requirements on the skill level and the work environment).
- Reparability requirements include a minimum availability of spare parts for inverters for at least 15 years, and availability of repair instructions for 7 years.
- Delivery of spare parts within 5 working days is mandatory.
- Replacement of certain parts is particularly relevant for inverters, and must be feasible for non-experts.
- Dismantling information on how to access junction boxes (if possible) must be made available to recyclers.
- Disassembly instructions complement design-for-repair requirements and provision of spare parts.
- An indication (weight range) of certain substances a product contains must be provided to create transparency on material content. EN 45558:2019 applies to

29 The European norm EN 50530 "*Overall efficiency of grid connected photovoltaic inverters*" describes the procedure for calculating the Euroefficiency or European efficiency (η_{EUR}), which is an average weighted efficiency for a full year of power distribution of a middle-Europe climate.

those listed as critical raw materials (CRMs) and a similar procedure applies to those that are currently not considered a CRM.

- Requirements on the carbon footprint of PV modules, which include the assessment of this indicator over the product life cycle from cradle to the location of installation. More details on these potential requirements are given in Annex I.

Energy label

The scope of the proposed regulation covers PV modules.

The energy performance of PV modules refers to an energy-efficiency index, which is calculated as the energy yield in direct current per unit area in three reference climates, calculated following standard EN 61853.

For PV modules, the label would display the following features:

- QR code;
- supplier’s name or trademark;
- supplier’s model identifier;
- scale of energy-efficiency classes from A to G;
- energy-efficiency class under ‘temperate coastal’, ‘temperate continental’ and ‘subtropical arid’ climate conditions;
- energy-efficiency index for PV modules (EEI_M) value in kWh/m^2 per year under ‘temperate coastal’, ‘temperate continental’ and ‘subtropical arid’ climate conditions;
- lifetime performance degradation rate;
- PV-module area, expressed in m^2; and
- wattage of the PV module.

Within the preparatory work on the Ecodesign and Energy Labelling for photovoltaic products, the technical and legal feasibility of an energy label for PV system has been evaluated. Further information on this, is presented in annex II to this document.

Test-standard references

When developing the working drafts for the regulations, about 50 test standards were consulted that related directly to the test or served as a normative reference. Calculation methods were also proposed and referenced. Overall, the draft proposal builds to the extent relevant and possible on the definitions and methods developed under the Commission mandates by the European standardisation organisations over the past 7-8 years. When necessary, transitional methods (for testing and calculating the parameters included in the working documents) have been prepared. However, at least for some of the current standards, the new regulations will require a new standardisation request to review the standards and bring them in line with the new regulations.

3. CONSULTATION OF INTERESTED PARTIES

The preparatory study followed the Methodology for Ecodesign of Energy-related products (MEErP). It was carried out between 2017 and end-2019 and included a technical, environmental and economic analysis assessing the need to set requirements and identifying the policy options.

The preparatory study was developed in an open process, taking into account input from relevant stakeholders, including manufacturers and their associations; environmental NGOs; consumer organisations; and Member State representatives. During the stakeholder consultation, advice from external experts was also collected and analysed.

To facilitate communication with stakeholders a dedicated website[30] was set up for the preparatory study. On this website, interim results and other relevant materials were published. During the course of the preparatory study, two open consultation meetings were held to discuss the study's outcomes. These open consultation meetings were attended by a wide range of stakeholders, including representatives from industry, NGOs and Member States.

In 2020-2021, as part of an extended study, several bilateral meetings with industry representatives, other stakeholders and individual experts were organised to update the data and the requirements from the impact assessment.

Pursuant to Article 18 of the Ecodesign Directive and Article 14 of the Energy Labelling Framework Regulation, Member State representatives and stakeholders will be formally consulted in the consultation forum. A consultation forum meeting on potential ecodesign and energy-labelling measures for PV modules, inverters and systems will take place in June 2022.

4. DISCUSSION TOPICS FOR THE CONSULTATION FORUM MEETING

The potential regulatory approaches presented in the working documents for this consultation forum meeting include potential ecodesign requirements that are not yet included in existing ecodesign legislation (although similar requirements are included in other EU legislation). Therefore, it can be expected that the discussions at the meeting will concern, among others, these topics, which are presented in the remainder of the section.

<u>Working document on potential ecodesign requirements</u>

- The ecodesign requirements presented in this working document affect either the energy efficiency of PV products (such as the euro-efficiency of inverters) or material-efficiency aspects (such as reparability and recyclability).

[21] https://susproc.jrc.ec.europa.eu/product-bureau//product-groups/462/documents

- Furthermore, current ecodesign measures do not cover two categories of requirements / conformity-assessment procedures, namely on:
  - the carbon footprint of the manufacturing and shipping phase of PV modules (described in more detail in Annex I); and
  - the quality control of the manufacturing process of PV modules and inverters.

The working document on potential ecodesign requirements shows how these new aspects could potentially be incorporated in implementing measures on ecodesign. Further assessment of the impact of these requirements on the potential supply of solar PV modules, and on the installation rate of these modules in the EU needs to be conducted. With the present energy constraints and the need to ramp up solar PV installations to reduce reliance of Russian fossil fuel imports, further assessments will be required. As such the draft Annex I indicates the level of ambition that is foreseen for these eco-design measures, but does not yet indicate the potential timing of their entry into force, which will be further assessed. The estimation of the economic and societal impacts in the light of the environmental objectives pursued by these measures will be carried out within the impact assessment analysis. This will also be accompanied by an estimation of the expected environmental impacts associated to the Ecodesign and Energy Labelling measures.

<u>Working document on potential energy-labelling requirements</u>

- The proposed energy-labelling scheme for PV modules has specific features when compared to products for which energy labels are mandatory already, as these schemes would target energy-generating products. In general terms, 'energy efficiency', when related to energy-conversion processes, represents conversion efficiency, for example the ratio of generated end-use energy to primary energy. When related to energy-consuming products, 'energy efficiency' can be regarded as the ratio of product performance (if it is possible to quantify it) to energy consumed (for example the light emitted by a light bulb for a given amount of energy). When applying the same approach to PV modules, a change of perspective is needed, as we are dealing with energy-generating products rather than energy-consuming ones. The 'energy efficiency' of energy-generating products is the ratio of the generated energy available for the final application to the incoming energy (being the incoming energy, the amount of solar radiation reaching the surface area covered by the relevant system or module).
- The proposed energy-efficiency index for PV modules (EEI_M) and the corresponding energy-efficiency class label quantify the gap between actual performance (i.e. the energy yield) and ideal performance. The IEC EN 61853 series defines that the module is ground-mounted on a fixed open rack facing the equator with an inclination angle of 20º, i.e. with fixed inclination and orientation representing a "reference condition" which is representative of a real installation. The EEI_M is calculated for the three reference climatic conditions relevant to the EU, defined as 'subtropical arid', 'temperate continental' and 'temperate coastal' these climates data sets are representative of real condition within Europe. All three values have to be displayed on the label. The energy label should accompany the product (i.e. the PV module) at a life-cycle stage (namely the placing on the market) when it is not possible for the manufacturer to know the specific place of installation.

ANNEX I - Requirements on the carbon footprint of the manufacturing and shipping phase of PV modules

The scope of the proposed draft regulations covers PV modules, among others. Two of the proposed provisions represent innovative regulatory approaches that have not yet been included existing ecodesign measures-, namely on:

- the carbon footprint of the manufacturing and shipping phase of PV modules; and
- the quality control of the manufacturing process of PV modules and inverters (in the form of an conformity assessment procedure).

The draft requirements on the carbon footprint presented in the ecodesign working document are set out below and indicate the level of ambition seen as necessary to improve the environmental footprint of solar panels used in the EU to the degree required to fulfil the European Union's environmental objectives. The timing is yet to be decided and will need to take into account evolving demand and that the EU is likely to have to increase solar panel installation rates.

From [ ], for photovoltaic modules models belonging to one of the categories below:

i. Multicrystalline Silicon photovoltaic modules (multi-Si)
ii. Monocrystalline Silicon photovoltaic modules (mono-Si)
iii. Cadmium-Telluride photovoltaic modules (CdTe)

the declared carbon footprint of photovoltaic modules referred to in point (d) of Part 2.1.4 of this Annex shall not exceed 25 gCO2eq/kWh.

From [ ], for photovoltaic modules models belonging to one of the categories below:

i. Multicrystalline Silicon photovoltaic modules (multi-Si)
ii. Monocrystalline Silicon photovoltaic modules (mono-Si)
iii. Cadmium-Telluride photovoltaic modules (CdTe)

the declared carbon footprint of photovoltaic modules referred to in point (d) of Part 2.1.4 of this Annex shall not exceed 18 gCO2eq/kWh.

From [ ], for photovoltaic modules models belonging to one of the categories below:

i. Copper-Indium-Gallium-Selenide photovoltaic modules (CIS / CIGS)
ii. Micromorphous Silicon photovoltaic modules (micro-Si)

a carbon footprint declaration shall be provided.

(Excerpt from Annex II to the ecodesign working document)

The scope of the proposed Ecodesign regulation excludes PV modules based purely on organic perovskite layers. Tandem solar cells made with silicon and these materials are inside the scope of this Regulation. Furthermore, PV modules based on new technologies entering the market with a cumulative global production less than 500 MW are also proposed to be out of the scope.

The carbon footprint of PV modules is largely determined at the design stage. First, the manufacturer's choice of materials and components in terms of their amount, origin and quality determines a module's overall carbon intensity. Second, a normalisation of the carbon intensity of these material inputs with the module's output, which is also largely determined by the design, determines the carbon footprint. Therefore, PV modules should be accompanied by a carbon-footprint declaration when placed on the market. This declared carbon footprint should not exceed a maximum threshold for multicrystalline silicon and monocrystalline silicon PV modules, which represent the vast majority of the market. This maximum threshold aims to remove the products with the highest emission impact from the market. These requirements will also create transparency on the market and enable consumers and public authorities to compare the carbon footprint of various PV modules placed on the market.

The proposed requirements on the carbon footprint of PV modules are fully consistent with the proposed regulation setting up a carbon border adjustment mechanism[31]. The carbon border adjustment mechanism aims to put a price on the carbon embedded in a limited set of mostly intermediate products imported into the EU. The requirements proposed here focus on making transparent and limiting the carbon footprint of a specific final product when placed on the EU market.

A potential method that could be used to calculate the carbon footprint is described in Annex IV to the ecodesign working document. This method builds on the product environmental footprint category rules for PV modules used in PV power systems for electricity generation (version 1.2, February 2020)[32]. The activity data to be collected and the default secondary datasets that could be used for each process are listed in the spreadsheet named 'CF_Annex_PV_modules-Life_cycle_inventory'[33]. Please note that the datasets used in the analysis supporting the working document (and in the analysis of the present explanatory memorandum) originate from the Environmental Footprint version 2.0[34]. The dataset list will be updated with the datasets of version 3.0 as soon as these will become available for PV modules. The maximum carbon-footprint threshold will then need to be recalculated, on the basis of the most recent available datasets.

Requirements on the carbon footprint of multicrystalline silicon and monocrystalline silicon PV modules

The analysis has been carried out on the basis of the various parameters set out in the table below. These parameters are related to PV-module characteristics and to the energy mix of the manufacturing phase, and are the most influential ones in determining the extent of the carbon footprint value and hence the overall environmental impact. Both yield

31 Proposal for a regulation of the European Parliament and of the Council establishing a carbon border adjustment mechanism, COM(2021) 564 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52021PC0564.

32 https://ec.europa.eu/environment/eussd/smgp/PEFCR_OEFSR_en.htm

33 https://ec.europa.eu/docsroom/documents/46532

34 Information on different data versions is available at: https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

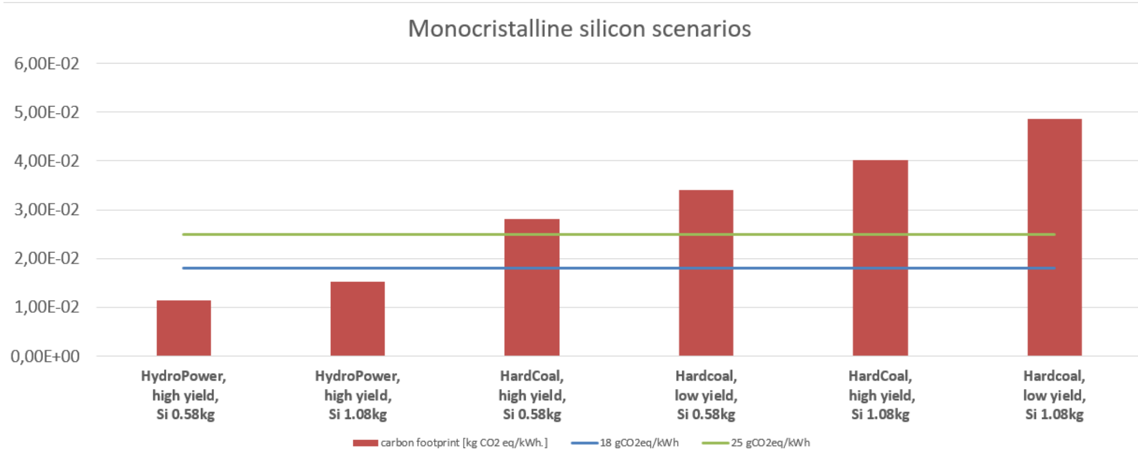
values are deemed to be representative of the current market (obviously, they correspond to various market segments: the top half of the market for the high yield value, and the lower part of the market for the low yield). In terms of quantity of silicon, the 'low' content should be the one typical of modules currently in production (the 'high' content being more representative of PV modules produced in the 2010s). The thresholds are obviously targeted to current module production.

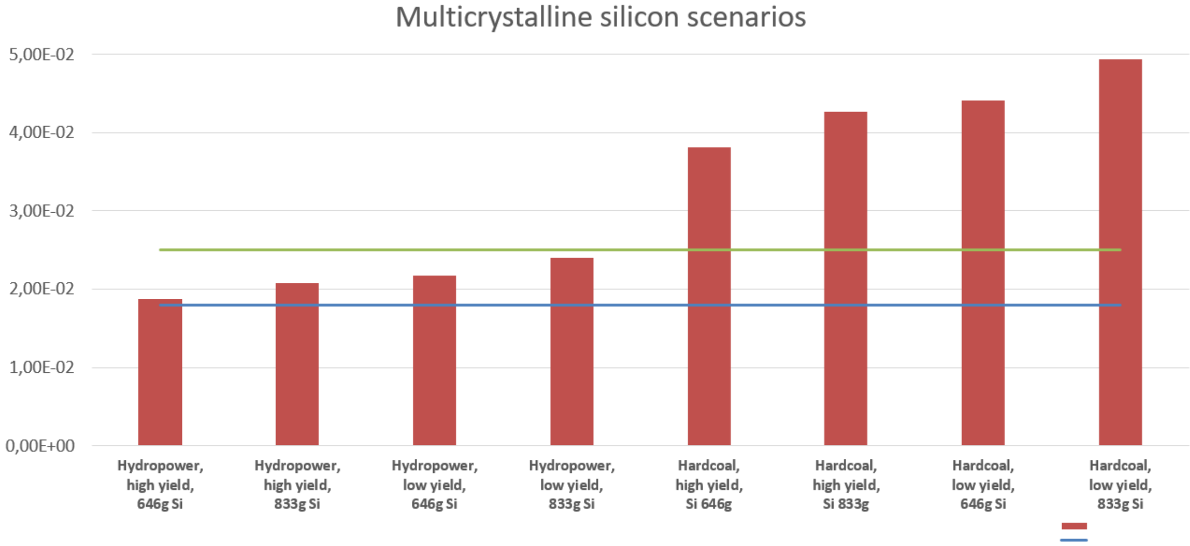
Parameter	High value	Low value	Notes
Silicon content (g per functional unit)			
Monocrystalline silicon	1 080	588	
Multicrystalline silicon	833	646	
Yield over 30 years[35] (kWh/m^2)			
Monocrystalline silicon	6 730	5 540	
Multicrystalline silicon	5 920	5 120	
Energy mix[36]	'hard coal' (worst) scenario	'hydropower' (best) scenario	

The following scenarios show the effect of the proposed maximum threshold for the carbon footprint of multicrystalline silicon and monocrystalline silicon. In both scenarios, the two thresholds are displayed (18 g CO_{2eq}/kWh and 25 g CO_{2eq}/kWh), with two differently coloured lines. Please note that the values on the y-axis in each scenario are expressed in **kg** CO_{2eq}/kWh. The first figure is related to monocrystalline silicon PV modules, and the second one to multicrystalline silicon PV modules.

35 Total energy yield in direct current over the service life (30 years), calculated according to Annex III, point 4.3, to the ecodesign working document.

36 Energy mix of the manufacturing phase.





On the effects of imposing a specific carbon-footprint maximum threshold (in terms of PV modules that would not be compliant with the thresholds), the figures above show clear differences between multicrystalline silicon and monocrystalline silicon PV modules. Therefore, and also considering the expected trend of a declining market share for multicrystalline silicon[37], the following two-stage approach is proposed:

- maximum footprint as of XX/YY/ZZ: 25 g Co_{2eq}/kWh → phase-out of inefficient multicrystalline silicon technologies;
- maximum footprint as of XX/YY/ZZ 18 g Co_{2eq}/kWh → phase-out of inefficient monocrystalline silicon technologies.

The regulatory approach presented in this section would be the first of its kind within Ecodesign implementing measures. Alternative approaches for regulating the carbon footprint of PV modules could also be proposed, such as:

- Ecodesign information requirement only;

[37] Bloomberg New Energy Finance, *Q1 2022 Global PV Market Outlook*, 1 March 2022.

- Carbon footprint information to be reported in the energy label of PV modules, and/or in the related product information sheet[38]
- quantitative requirements on specific relevant parameters influencing the carbon footprint, such as the silicon content or the module yield.

Feedback on all these potential approaches is expected from stakeholders at the consultation forum meeting, and/or within the 4 weeks period (after the meeting) for comments.

Requirement on the carbon footprint of thin-film PV modules

The regulatory approach described in the working document for thin-film PV modules (with the exception of CdTe technology) consists of a compulsory information requirement. Thin-film PV modules represent a minor share of the global market (less than 10%).

Thin-film technologies – with the exception of CdTe technology – are either for ultra-niche sectors such as PV modules for spatial applications, or still not fully deployed on the market. In both cases, no sufficient data were available from the market to carry out the analysis for quantitative requirements on the carbon footprint.

PV modules using CdTe technology usually have a carbon footprint that is well below the one of multicrystalline silicon and monocrystalline silicon. For the principle of technological neutrality, they will be subject to the same requirements for silicon based modules.

[38] This option shall be accompanied by an analysis on the legal feasibility of the approach (in particular with regard to the provision laid down in Article 16(3)(c) of the Energy Labelling framework Regulation 2017/1369: 'supplementary information shall […] be based on data relating to physical product characteristics that are measurable and verifiable by market surveillance authorities.'

ANNEX II – Energy label for PV systems

Within the preparatory work on the Ecodesign and Energy Labelling for photovoltaic products, the technical and legal feasibility of an energy label for PV system has been evaluated. Further information on this, is presented in this annex.

While the analysis shows the technical feasibility for such label (see the remainder of this annex), legal considerations on the role of installers of PV systems as 'suppliers', and the consequent obligation[39] to fill the EPREL database for each installed system, finally led to exclude the energy label for PV systems from the working document on Energy Labelling (with a view to minimise the administrative burden on economic operators in the field).

The provision of an energy label for PV systems would also entail obligation on dealers, in particular for them to ensure that '*any offer for a specific photovoltaic system includes the energy efficiency class for the 'temperate coastal', 'temperate continental' or 'subtropical arid' climate conditions, as applicable, the total energy generated and the total photovoltaic modules area, by displaying with the photovoltaic system the label set and providing the fiche, duly filled in according to the characteristics of that photovoltaic system*'

The technical features of the potential energy label for PV systems are given below.

Draft technical proposal for an energy label for PV systems

The scope of the proposed label covers PV systems of up to 20 kW.

The proposed energy-labelling scheme is intended for small PV systems (of up to 20 kW) typically used for residential or small commercial buildings.

A PV system could be defined as 'a power system designed to supply usable electrical power. It consists of an arrangement of several components, including photovoltaic modules and associated balance-of-system components (BOS) like solar inverters, wiring, mounting elements, switches, combiners, disconnectors, circuit breakers, and/or storage devices as battery banks and chargers. The photovoltaic modules belonging to one photovoltaic system are all installed with, at maximum, two different orientations of two sub-arrays of PV modules'

The energy performance of PV systems refers to an energy-efficiency index, which is calculated as the energy yield per unit area of the proposed PV system, following standard EN 61853.

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[39] In order to remove this obligation, it would be necessary to modify the framework Energy Labelling Regulation 2017/1369.

Further definitions needed for PV systems

(1) 'Energy Efficiency Index' (EEI_S) of a photovoltaic system means the ratio of the AC energy yield delivered by the photovoltaic system ($EY_{S(AC)\_LT}$) over its entire lifetime, which is assumed of 30 years, under a reference climate condition and expressed in kWh, divided by the total area of the photovoltaic modules that form the system (A_S), expressed in m^2;

(2) 'Degradation rate (τ_{deg}, %/year)' of a photovoltaic system means the annual percentage decrease of the photovoltaic system's power output, when compared to the initial value. The lifetime degradation rate of the photovoltaic system (τdeg) is assumed equal to the lifetime degradation rate of the photovoltaic modules (τdeg) that form part of the system.

(3) 'Photovoltaic inverter' means an electric equipment, used to convert DC power from a PV array into a form suitable for subsequent use as to single-phase or poly-phase alternating currents (AC);

(4) 'Euroefficiency' means the overall efficiency of grid connected photovoltaic inverters for a full year of power distribution of a middle-Europe climate;

(5) 'Total energy generated over 30 years' of a photovoltaic system means the EEI_S multiplied by the total area of the photovoltaic modules that form the system (A_S).

Energy Labelling scheme – thresholds for the energy labelling classes

The energy efficiency class of a photovoltaic system shall be determined on the basis of its Energy Efficiency Index (EEI_S) as set out in Table 2.

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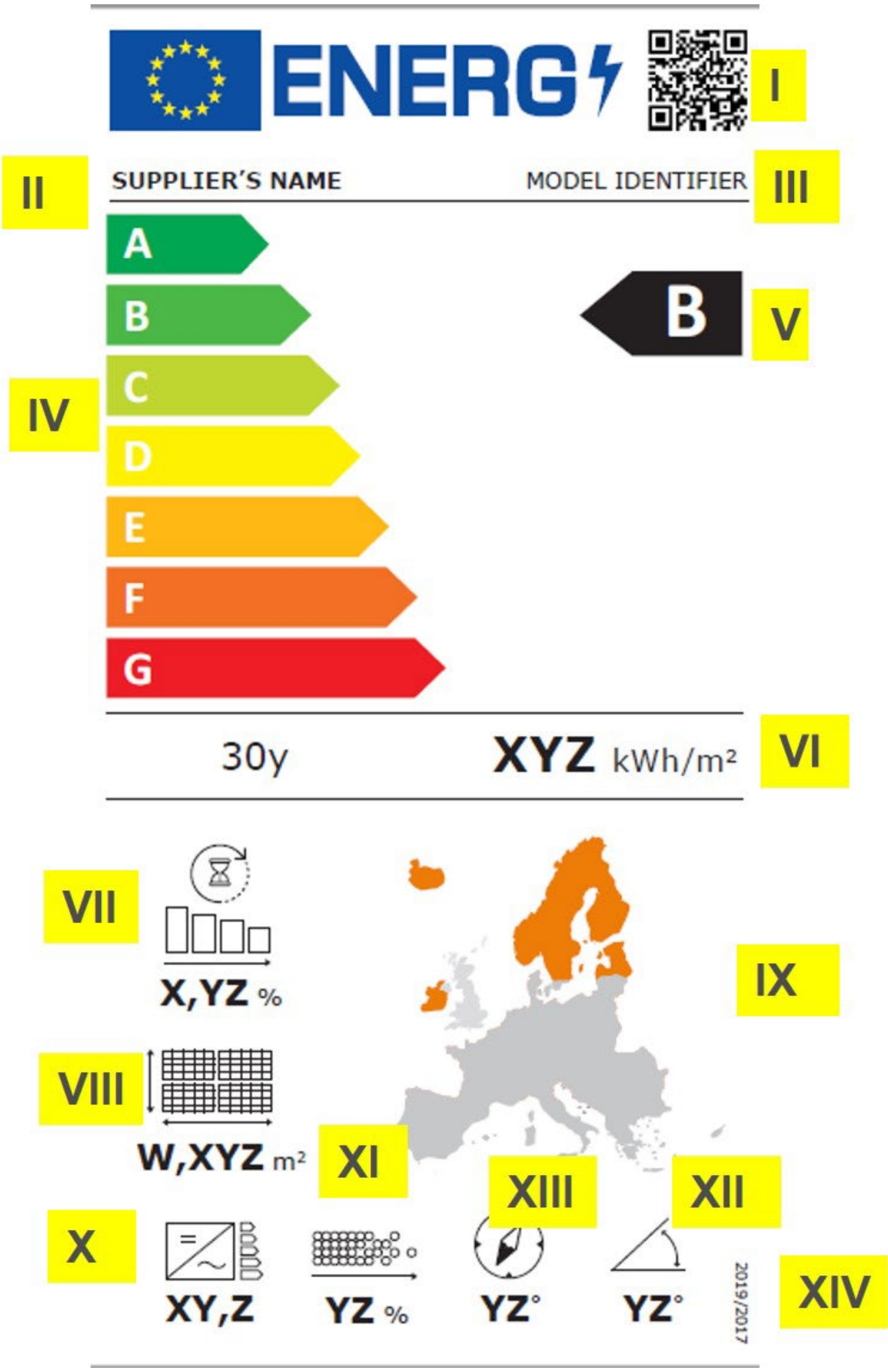
Table 2
Energy efficiency classes of photovoltaic systems

	Energy Efficiency Index (EEI_S), kWh/m^2		
Energy Efficiency Class	**Subtropical arid**	**Temperate coastal**	**Temperate continental**
A	$\mathbf{EEI_S} > 13974$	$\mathbf{EEI_S} > 6388$	$\mathbf{EEI_S} > 8232$
B	$11659 < \mathbf{EEI_S} \leq 13974$	$5343 < \mathbf{EEI_S} \leq 6388$	$6899 < \mathbf{EEI_S} \leq 8232$
C	$9345 < \mathbf{EEI_S} \leq 11659$	$4298 < \mathbf{EEI_S} \leq 5343$	$5566 < \mathbf{EEI_S} \leq 6899$
D	$7031 < \mathbf{EEI_S} \leq 9345$	$3253 < \mathbf{EEI_S} \leq 4298$	$4233 < \mathbf{EEI_S} \leq 5566$
E	$6076 < \mathbf{EEI_S} \leq 7031$	$2766 < \mathbf{EEI_S} \leq 3253$	$3589 < \mathbf{EEI_S} \leq 4233$
F	$5122 < \mathbf{EEI_S} \leq 6076$	$2279 < \mathbf{EEI_S} \leq 2766$	$2946 < \mathbf{EEI_S} \leq 3589$
G	$\mathbf{EEI_S} \leq 5122$	$\mathbf{EEI_S} \leq 2279$	$\mathbf{EEI_S} \leq 2946$

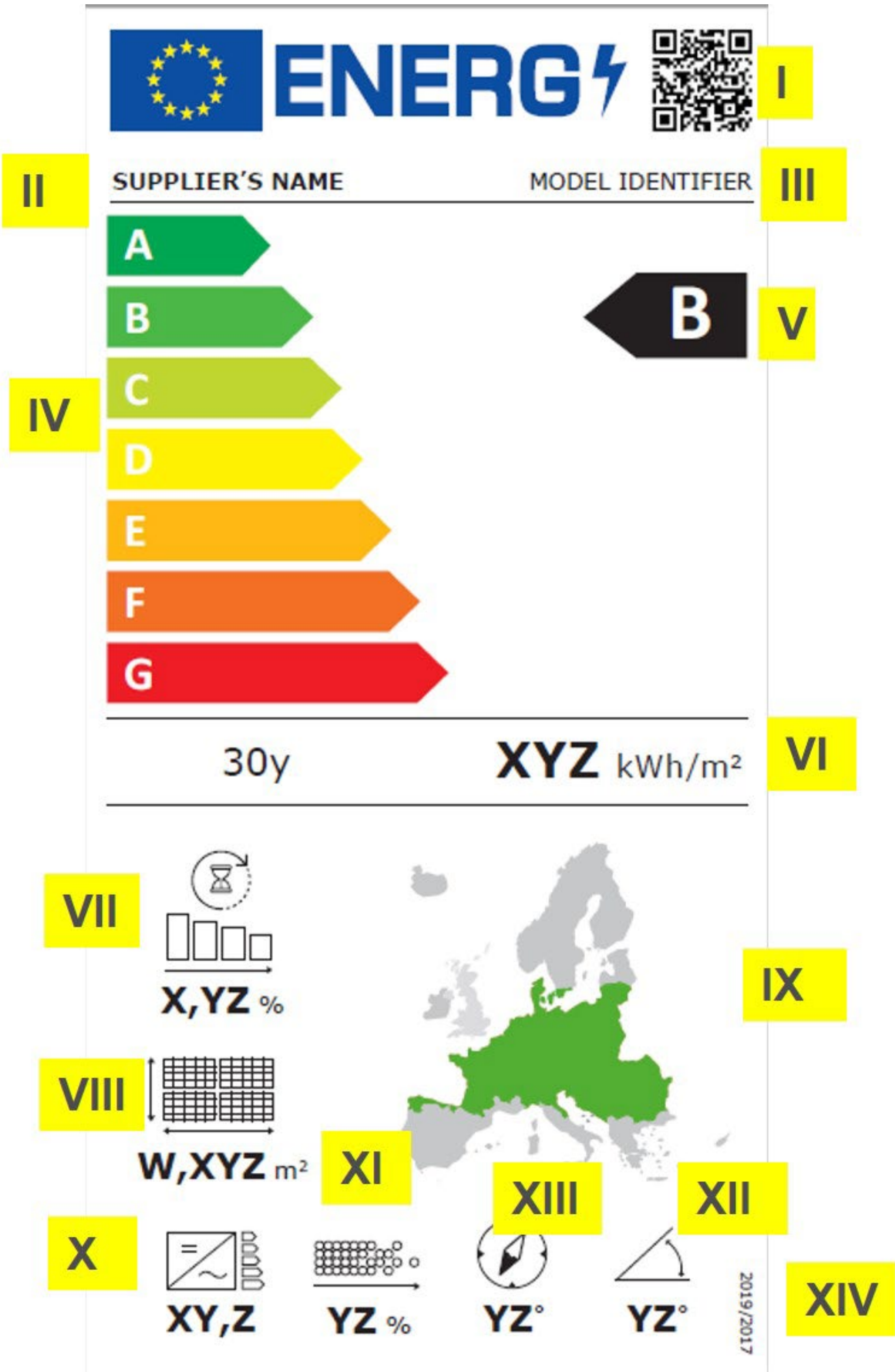
Energy Labelling scheme – design of the energy label

LABEL FOR PHOTOVOLTAIC SYSTEMS

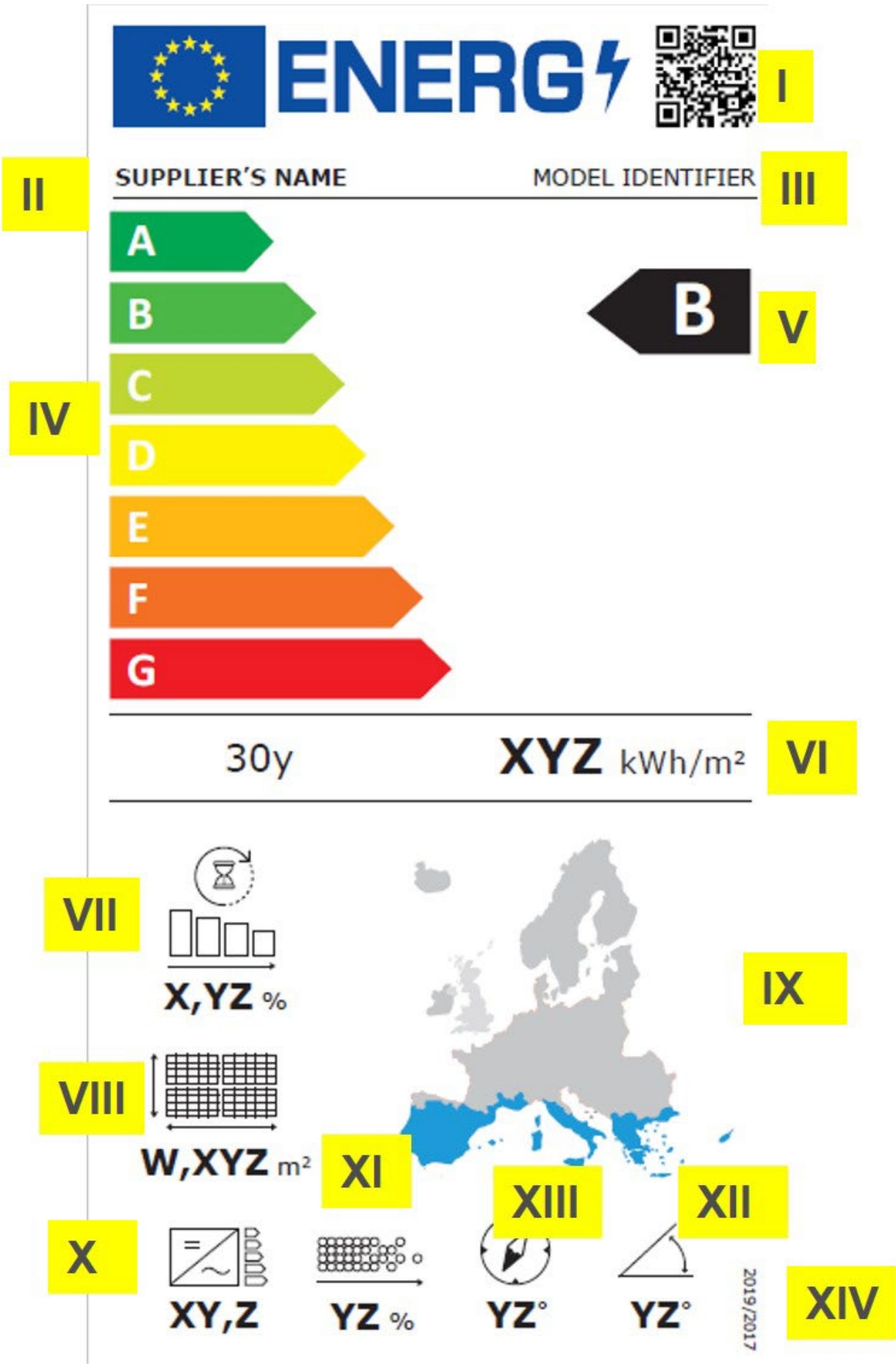
1 Label for photovoltaic systems for ‘temperate coastal’ climatic area



2 Label for photovoltaic systems for 'temperate continental' climatic area



3 Label for photovoltaic systems for ‘subtropical arid’ climatic area



4. The following information would be included in the label:

I. QR code;

II. supplier’s name or trade mark;

III. supplier’s model identifier;

IV. scale of energy efficiency classes from A to G;

V. the system energy efficiency class EEI_S under 'temperate coastal', 'temperate continental' or 'subtropical arid' climate conditions as applicable, determined in accordance with Annex II;

VI. The system energy efficiency index value EEI_S under the applicable 'temperate coastal', 'temperate continental' or 'subtropical arid' climate conditions, calculated according to Annex IV, expressed in kWh/m^2 and rounded to the first decimal place;

VII. the lifetime performance degradation rate, expressed in % and rounded to the second decimal place;

VIII. the total photovoltaic modules area, expressed in m^2 and rounded to the third decimal place;

IX. the climatic area of the place of installation of the photovoltaic system;

X. the inverter system efficiency at 25% of nominal power, expressed in % and rounded to the first decimal place, for photovoltaic systems equipped with photovoltaic inverters with possibility to connect storage or with integrated storage, or the inverter euroefficiency, expressed in % and rounded to the first decimal place, in all other cases;

XI. the total system losses expressed in % and rounded to the first decimal place;

XII. the inclination of the photovoltaic modules of the photovoltaic system;

XIII. the orientation of the photovoltaic modules of the photovoltaic system;

XIV. the number of the Regulation.

Energy Labelling scheme – testing and calculation method

ENERGY EFFICIENCY INDEX OF A PHOTOVOLTAIC SYSTEM (EEI_S)

The EEI_S is expressed in kWh/m^2 and calculated as follows for the applicable climatic condition 'temperate coastal', 'temperate continental' or 'subtropical arid':

$$EEI_{S\,c} = {EY_{S(AC)\,LT\,c}}\Big/{A_S}$$

$$EEI_S = EY_{S(AC)\_LT} / A_S$$

Where:

- $EY_{S(AC)\_LT\,c}$ is the lifetime AC energy yield from the photovoltaic system under the climatic conditions in the applicable reference climate, expressed in kWh.
- A_S is the total area of the photovoltaic modules that form the system expressed in m^2.

The orientation, inclination of the PV modules must be provided. Effect of degradation of the various components and the effect of various losses, such as soiling or presence of shadows by surrounding obstacles are considered in the $EY_{S(AC)\_LT}$ estimation. Ground albedo is only considered for ground-mounted photovoltaic systems that include bifacial modules.

TRANSITIONAL METHODS FOR THE CALCULATION OF THE ENERGY EFFICIENCY INDEX OF A PHOTOVOLTAIC SYSTEM (EEI_S)

Table

References and qualifying notes for photovoltaic inverters

Parameter	Source	Reference Test Method	Notes
Euroefficiency	CENELEC	EN 50530:2010/A1: 2013	Overall efficiency of grid connected photovoltaic inverters. For inverters with built in or dedicated batteries and connection/software, the value corresponds to performance with a fully charged battery. Report resulting efficiency for each of the partial MPP power levels used in formula D.1 for the calculation of the Euroefficiency
Efficiency curve for PV inverters with possibility to connect storage or with integrated storage	Bundesverband Energiespeicher (Germany)	Guideline for PV Storage Systems 2.0 / Effizienzleitfaden für PV-Speichersysteme 2.0, 2019	German and English versions available at https://www.bves.de/effizienzleitfaden_2/
Smart readiness	IEC	IEC 61724-1:2017 ED1	Class C data monitoring
Connectivity	CENELEC	EN IEC 61158	Connectivity with other devices
Communication with distribution networks	CENELEC	50549	

Table

References and qualifying notes for photovoltaic systems

Parameter	Source	Reference Test Method	Notes
Climate Specific Energy Rating (CSER)	CENELEC	EN IEC 61853-3	Requires the values calculated for the three relevant reference climates defined in EN IEC 61853-4 that best represent the European climatic conditions (Subtropical arid, Temperate continental and Temperate coastal)…..
PV module STC power output	CENELEC	EN 50380	
PV module area	CENELEC	EN 50380	
Nominal system power DC		EN 61724	Number of module time nominal module power
Relevant climatic zone		Not available	Which of the three reference climates from IEC 61853-4 corresponds to the location of the PV installation (- https://ec.europa.eu/docsroom/documents/46531).
Lifetime AC energy yield		See Part 2 of annex IVa to this Regulation	

Part 2 – Transitional methods for specific parameters

Calculation method for the energy yield from bifacial photovoltaic modules

Calculation method for the energy yield from photovoltaic systems

The lifetime AC energy yield from a PV system ($EY_{S(AC)\_LT}$, kWh) is estimated in various steps that represent the performance of its main components, the losses due to external factors and the effect of degradation of the whole system on its lifetime performance. The two main components, the PV array and the inverter are modelled in the first two steps, in which the losses due to their intrinsic characteristics are already considered. In a subsequent step, the PV system losses are considered and included in the AC energy yield estimation from the complete PV system. The last step of the methodology accounts for the lifetime performance of the system.

Step 1. PV array annual DC energy yield – PV module performance

The DC energy yield from the PV array over one year ($EY_{A(DC)\_Y1}$, kWh), which is considered the first year of installation, is calculated following the same method used to estimate the DC energy yield from a single module ($EY_{M(DC)\_Y1}$), but extrapolating for the whole PV array as follows:

$$EY_{A(DC)\,Y1} = EY_{M(DC)\,Y1} \cdot N_M$$

Where:

$EY_{M(DC)\_Y1}$ is the DC energy yield from one photovoltaic module over its first year of installation under the climatic conditions of the applicable reference climate, expressed in kWh.

N_M is the number of photovoltaic modules that form the array or system.

Step 2. PV array annual AC energy yield - Inverter performance

The AC energy yield from the PV array over one year ($EY_{A(AC)\_Y1}$, kWh), which is considered the first year of installation, is calculated from the annual DC energy yield from the PV array over the same time period ($EY_{A(DC)\_Y1}$) and the inverter's Euroefficiency (μ_{Euro}), as follows:

$$EY_{A(AC)\,Y1} = EY_{A(DC)\,Y1} \cdot \mu_{Euro}$$

Where:

$EY_{A(DC)\_Y1}$ is the DC energy yield from the PV array over its first year of installation under the applicable reference climate conditions, expressed in kWh.

μ_{Euro} is the inverter's Euroefficiency, expressed in decimal format. An Euroefficiency of 97.5% should be applied here as 0.975.

Step 3. PV system losses

The PV system losses have two components:

a. A fixed baseline loss of 10%, and
b. a variable component which depends on the following factors:
   i. PV system elements: PV module, inverter, storage
   ii. PV system installation and configuration:
1) inclination and orientation of PV array
2) presence of nearby obstacles
3) presence of very dusty or polluted environment
4) non-optimal configuration

The variable component is estimated based on the check list below to be filled in at the moment of the installation, and a series of default losses values.

i	Cause of loss	Applied loss factor, Lf_i (%)
1	Baseline (mandatory)	14
2	Shading from objects within 10m of the system (chimneys, antenna, trees etc.)	3
3	Shading from objects beyond 10m of the system (buildings, large trees etc.)	3
4	Surrounding horizon with hills and mountains block the sun	3
5	Extensive wiring required (distance from PV array to inverter above 10m)	2
6	Installation in a particularly polluting or dusty environment (polluting industrial area)	2
7	Physical separation of array in sections with or without different orientation	2

The PV system losses (L_S) are calculated from the multiplicative contribution of the fixed baseline losses and all the applicable variable losses factors (from i=1 to i=n), as follows:

$$L_S(\%) = 100 \cdot \left[1 - \left(\prod_{n=1}^{n}(1 - 0.01 \cdot L_{fi})\right)\right]$$

Where:

Lf_i is the loss factor i expressed in %

Step 4. PV system annual AC energy yield

From the annual PV array AC energy yield ($EY_{A(AC)\_Y1}$) estimated at Step 2 and the PV system losses (L_S) defined in Step 3, it is possible to estimate the annual PV system AC energy yield ($EY_{S(AC)\_Y1}$) assumed for the first year of installation, by considering the various losses as derating factors of the AC energy yield delivered by the inverter.

$$EY_{S(AC)\,Y1} = EY_{A(AC)\,Y1} \cdot (1 - 0.01 \cdot L_S)$$

Where:

$EY_{A(AC)\_Y1}$ is the AC energy yield delivered by the PV array over the first year of installation under the applicable reference climate conditions, expressed in kWh.

L_S is the PV system losses, expressed in %.

Step 5. PV array lifetime AC energy yield

Up to this point the estimation of the AC energy yield of the PV system is done assuming a new installation where components have not yet been subjected to degradation. However, degradation can play an important role on the performance of a PV system over its lifetime, which is assumed as 30 years.

The lifetime AC energy yield from a PV system ($EY_{S(AC)\_LT}$) is estimated assuming constant over the years both the solar radiation received by the PV array and the PV system losses. These assumptions result in a constant yearly AC energy yield over the PV system lifetime as well, and equal to the value estimated in the Step 4. The effect of degradation of the different components is accounted for by applying a linear degradation factor which decreases the yearly AC energy yearly year by year. The sum of these "degraded" yearly AC energy yield over the lifetime of the PV system is the estimation of its lifetime AC energy yield, expressed in kWh.

$$EY_{S(AC)\,LT} = EY_{S(AC)\,Y1} \cdot T_{LT} \cdot \left(1 - \tau_{\deg S} \cdot \left({}^{T_{LT}}/_{2}\right)\right)$$

Where:

- $EY_{S(AC)\_Y1}$ is the AC energy yield delivered by the PV system over the first year of installation under the applicable reference climate conditions, expressed in kWh.
- T_{LT} is lifetime of the PV system, which is assumed as 30 years.
- τ_{deg_S} is the PV system lifetime performance degradation rate, expressed here in decimal format. A degradation rate of 1% should be applied here as 0.01.

Definition of the photovoltaic module and photovoltaic system lifetime performance degradation rates

The degradation rate τ_{deg} for each PV module category is defined as the annual percentage decrease of the PV product's energy yield, when compared to the initial value, assuming the decrease to be constant in time and considering the same testing conditions under which the initial value was measured. If EY_0 is the initial value of the energy yield, τ_{deg} can thus be expressed by:

$$\tau_{deg} = \left(\left(\frac{EY_t}{EY_0}\right) - 1\right) \cdot \left(\frac{1}{t}\right)$$

Where:

EY_t is the value of the energy yield after an amount of years equal to t. The degradation rate τ_{deg} is expressed in %/year:

- Degradation rate for silicon photovoltaic modules: 0.7 %/year;
- Degradation rate for thin film and heterojunction photovoltaic modules: 1 %/year.

Lower values can be declared provided they are based on experimental data collected from the measurement of field deployed systems. These data shall:

- cover at least five consecutive years
- be collected at least in two separate geographic locations in each of the three reference climatic conditions
- contain open rack ground-mounted, roof-mounted and building added systems (at least 2 of the three options must be included).

The assigned degradation rate shall be the average of all collected degradation rates from above. The lifetime degradation rate of the PV system (τ_{deg_S}) is assumed equal to the lifetime degradation rate of the PV modules (τ_{deg}) that form part of the system.

The below xls file consists in a tool, prepared by the Commission, to carry out the EEIS assessment in line with the provisions above.

PV system tool (split array).xlsm

Further technical considerations

For PV systems, the proposed energy-efficiency index (EEI_S) rests on a slightly more complicated approach than the EEI_M. The EEI_S express a system's lifetime performance (i.e. the energy yield) compared to the performance of a reference PV system installed facing the equator with an inclination angle of 20º. This reference PV system implies the best conditions/choices related to the following parameters/components/features:

iii. components of the PV system: PV module, inverter and storage; and

iv. installation and configuration of the PV system:

1. presence of nearby obstacles;
2. presence of very dusty or polluted environment; and
3. optimal system configuration.

Specifically referring to the inclination and orientation of a PV array, it has to be noted that the boundaries of the EEI_S classes have been calculated based on the reference system's set-up, i.e. facing south with an inclination of 20º. When calculating the EEI_S of a PV system that is not optimally inclined nor oriented (e.g. for reasons linked to the available space / orientation of the building / choice to install the modules vertically), the EEI_S of this PV system will be different from that of the same system when installed in the reference configuration (typically, it will be lower). Another approach (not implemented in the working documents, but also conceivable) could consist in calculating the EEI_S of a specific PV system and the corresponding class by comparing (i.e. normalising) it with the best possible system with the same inclination and orientation. In line with this alternative approach, the energy-efficiency classes or energy-label boundaries would depend on the installation (orientation and inclination) considered. In this case, the energy labels assigned to the system under consideration would not be negatively influenced by the large difference in orientation and inclination compared to the reference system (south facing with 20º inclination angle). This is because both the system under consideration and the reference system would be assumed to be installed in the same orientation and with the same inclination angle.