Building Criteria for Energy Labeling of Photovoltaic Modules and Small Systems

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As part of the Ecodesign framework, the European Union’s energy-labeling scheme has proved to be a powerful tool to communicate with consumers regarding the energy use of products. With sales of photovoltaic (PV) modules and small systems set to expand rapidly for the European Union to meet its commitments on CO₂ reduction, ensuring that newly installed PV products in the European Union are environmentally friendly and do not create future burdens on the environment is of primary importance. Herein, an innovative methodology in support of a potential energy-labeling scheme for both PV modules and PV systems (installations) is proposed. The estimated annual and lifetime yields for a PV module and system respectively are used as parameters for classification from A (best) to G (worst) in the proposed scheme. How to “translate” the methodology into a practical energy-labeling scheme, i.e., for use in EU policy implementing measures, is also discussed. The conceptual challenges of proposing an energy label for energy-generating products, i.e., PV modules and systems, are also discussed.

1. Introduction

Photovoltaics is a key technological sector. The European Union (EU) cumulative installed capacity of 138 GWDC in 2020 is projected to grow by 2030 to some 440 GWDC (assuming a scenario with a 55% greenhouse gas reduction) and to expand further in the long term.[1] A future annual market of 20 GW translates to ≈50 million photovoltaic (PV) modules. Residential, commercial, and industrial rooftop installations are expected to continue to represent a sizable part of the market. A share of 20% could amount to 6 GW per year, or about 1,200,000 systems. It is therefore of primary importance to ensure that newly installed PV products in the EU are environmentally friendly and do not create future burdens on Europe’s environment. In particular, the energy yield of PV systems can potentially be improved through a combination of better design to take into account site-specific conditions, best installation practices, and reducing losses thanks to selecting and coupling the most appropriate equipment with adequate cabling and maintenance. A 2019 preparatory study on the environmental impacts—and related policy approaches at EU level—of PV modules, inverters, and systems[2] conducted by the European Commission Joint Research Centre concluded, inter alia, that improvements in the energy yield and long-term performance of PV modules, inverters, and systems could be ensured by mandatory legal instruments, in particular via the synergic application of implementing measures in the framework of the Ecodesign Directive[3] and labeling schemes in the framework of the Energy Labelling Regulation.[4]

Implementing measures (i.e., regulations) in the framework of the Ecodesign directive and the Energy Labelling Regulation typically foresees the use of harmonized standards, adopted by recognized European standardization organizations (European Committee for Standardization (CEN) or European Committee for Electrotechnical Standardization (CENELEC)), for the testing and calculation methods necessary for the compliance assessment. However, when harmonized standards are not available, other already existing standards or methods may be considered when it is proved that they are suitable to the extent of assessing the compliance of products with the applicable requirements (Ecodesign or energy labeling). An extensive review of available standards for the characterization of the performance of PV modules and PV systems[5] identified important aspects that are not yet the subject of a published standard for the implementation of EU legislation to PV products. At present, parameters such as the expected energy yield delivered by a PV system over its lifetime or the lifetime itself of PV modules or systems are neither defined nor modeled in any standard. Therefore, transitional methods are needed to define these and other concepts necessary to implement Ecodesign and energy-labeling schemes on PV products.[6] An additional aspect is the increasing deployment of bifacial PV modules,[7] which are not yet fully considered in the existing standardization framework. To deal with this significant and growing...
market segment within the Ecodesign and energy-labeling framework, additional transitional methods are required.

The aim of this article is twofold: first, to devise in detail the policy approach related to the energy labeling and second to contribute to the knowledge base by proposing a methodology and calculation procedure in support of potential energy-labeling schemes for both PV modules and PV systems (installations). The estimated annual and lifetime yields per unit area for PV modules and systems respectively are used as a parameter for classification from A to G in the proposed energy-labeling scheme. The article also elaborates on how to “translate” the methodology into an actual energy-labeling scheme, i.e., for use in EU policy-implementing measures. The conceptual challenges of proposing an energy label for energy-generating products, i.e., PV modules and systems, are also discussed.

This article is organized in four sections. Section 2 gives background information on the energy-labeling policy, on the ongoing work on PV modules and systems, and on the state-of-the-art procedures for the measurement and calculation of the performance of PV products. Section 3 presents a model for the characterization of the performance of PV modules and PV systems over their lifetime, and Section 4 shows how the technical research work of the previous section can be “translated” into EU policy implementing measures, namely on energy-labeling schemes. Finally, Section 5 summarizes the main findings and possible implications of the study.

2. Background

2.1. The Energy-Labeling Policy and the Work on PV Modules and Systems

The current EU sustainable product policy is aimed to drive the market toward the production and consumption of more sustainable products. This policy targets, with a number of legislative tools, the various life cycle stages of products, such as product design, materials, manufacturing, use, end of life, and the related use of energy, water, chemicals, and other resources.

In terms of mandatory instruments, the Ecodesign Directive requires manufacturers placing products on the EU market to improve their environmental performance by meeting mandatory minimum energy efficiency requirements, as well as other obligatory environmental requirements such as water consumption, emission levels, or material efficiency aspects. The Energy Labelling Regulation provides consumers with a straightforward informative tool to make a better purchase choice, by grading products according to a well-known A–G/green-to-red seven-class label. At the same time, it encourages manufacturers to drive innovation using more energy-efficient technologies. The Ecodesign regulatory process foresees reviews of the existing regulations at regular intervals to cope with the technology, market, or legislative evolution, so if necessary the requirements and calculations methods can be updated to reflect technology innovations or the availability of new standards.

With specific regard to the energy-labeling policy, the 2019 preparatory study on the environmental impacts of PV modules, inverters, and systems referred to in Section 1 concluded that an energy label for PV could be used to introduce energy classes to provide information to customers. A more recent article devised a more articulated proposal, foreseeing a regulatory approach with two energy labels, one for PV modules and the other one for PV systems (installation) up to a certain level of installed peak power (currently proposed as equal to or less than 30 kW), with the aim to cover residential and possibly small commercial installations. For the utility-scale segment, the case for proposing an energy label as an information tool is weaker because the professionals involved in the design and procurement phases of such systems already have access to sophisticated and tailored tools for the evaluation of their performance.

2.2. Estimation of PV Module and PV System Performance

Concepts such as the degradation of PV modules, lifetime of PV systems, or the expected long-term performance of PV systems and their components (such as inverters) under real working conditions are still the subject of debate and scientific investigation. No European or international standards that define or model these parameters exist. Nonetheless, they are fundamental for the implementation of the policy tools discussed in this article.

Therefore, as part of the preparatory study mentioned in Section 1 and 2.1, various methods were analyzed and compared to propose a methodology to define these concepts. In addition to a procedure to define the degradation rate of PV modules, or the lifetime of PV systems, in the preparatory study several methods were developed to model the effect of the main components of a PV system such as the inverter on the system’s performance and how to deal with system losses. For example, four different methods were evaluated to model the long-term performance of PV inverters. Each represents a compromise between accuracy and the limitations of the information typically made available by manufacturers.

The concatenation of the selected models representing each component of the PV system results in a methodology to model and quantify the lifetime performance of PV systems, as shown in Figure 1. The proposed methodology estimates the AC energy yield delivered by a PV system over its lifetime under real working conditions, taking into account the efficiency and performance of the various components, as well as the effect of various losses and the annual degradation rate.

The electrical performance of PV modules can be estimated following the IEC 61853-x series, which defines a methodology to estimate the DC energy yield of the PV device over 1 year under real working conditions (no degradation applied). These are defined by six different climatic reference datasets which describe the most representative worldwide climatic conditions. Three of these reference climates are relevant for Europe: subtropical arid, temperate coastal, and temperate continental, and will be applied for the EU policy tools discussed in this article.

Although the first step of the complete methodology to estimate the AC lifetime energy yield from a PV system is based on the IEC 61853-x series, the other steps in the calculation process rely on transitional methods defined in the preparatory study. Notwithstanding, because the IEC 61853-x standard’s scope only covers monofacial PV devices, a transitional method was developed as well to extend the IEC 61853 methodology to bifacial devices and estimate the DC energy yield from this type of PV module, based on recent research in the EU-funded PV-ENERATE project.

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As shown in Figure 1, the complete methodology to estimate the lifetime AC energy yield from PV systems is divided in two parts. The first part results in the estimation of the AC energy yield of the PV system for the first year of installation, taking into consideration the performance of the PV array, inverter, and the effect of various losses derived from the installation and configuration of the PV system. The second part of the methodology accounts for the lifetime performance of the PV system taking into consideration the degradation of the PV system. The AC lifetime energy yield is estimated assuming a linear degradation rate over a lifetime of 30 years.

3. Proposed Tool for the Estimation of the PV Module and PV System Performance

In the proposed energy label scheme for PV modules and systems developed by the Joint Research Centre the energy efficiency index (EEI) is calculated from the total energy yield delivered by the PV module or system and their respective areas. The former is calculated according to the methods defined in the IEC 61853-x series (or extended methodology for bifacial devices), while the latter is estimated based on the methodology defined in the transitional method described in Section 2.2.

In both cases, the energy yield is to be estimated considering the climatic reference datasets as defined in the IEC 61853-4 [10] that are relevant to Europe: subtropical arid, temperate coastal, and temperate continental. However, whereas the DC energy yield of a PV module is calculated over the first year of installation (without considering degradation), the AC energy yield of a PV system would represent the complete lifetime of the PV system, for which losses and degradation must be accounted for.

Another difference regards the configuration of the module and system. The PV module is assumed installed, as defined in the IEC 61853-x series, in a freestanding rack facing the equator with an inclination angle of 20°. However, the PV system can be defined with any orientation and inclination angle and may be installed as a ground-mounted rack or attached to a building.

Based on the estimated energy yields, the PV module energy efficiency index (EEIM) is calculated as the ratio of the DC energy yield delivered by one PV module over the first year of installation, divided by the module’s area, expressed in kilowatt hour per meter squared. The energy yield shall be calculated for the three reference climates as it is not possible a priori for the manufacturers to know the place of installation of the modules.

The PV system energy efficiency index (EEIS) is calculated as the ratio of the lifetime AC energy yield delivered by the PV system divided by the PV array area, expressed in kilowatt hour per meter squared. This EEI allows differentiation for technological and installation factors and avoids a system size bias; i.e., different array sizes in terms of installed peak power for the same type of PV system (components and configuration), even though they would deliver a different AC energy yield according to their size (kWh), would obtain the same EEIS (kWh m⁻²). The energy yield of the PV system is to be calculated for the relevant reference climate for the location where the PV system will be installed, from the three European reference climates.

The required input parameters for the calculation respectively of the PV module EEIM and the PV System EEIS are shown in Table 1.

An Excel tool has been developed to estimate both the PV module and PV system energy yield according to the methodologies described in Section 2.2. The tool also estimates the EEIM and EEIS values—starting from the input parameters of Table 1—and will be available for users and installers to run the simulations.

4. Building an Energy Label for PV Modules and Systems

4.1. How to Define the “Energy Efficiency” of Energy-Generating Products

In general terms, “energy efficiency,” when related to energy conversion processes, represents the conversion efficiency, i.e., the
Table 1. The required input parameters for the calculation the energy efficiency index respectively of the PV module EEIM and the PV system EEIS.

| Parameter                  | PV module (DC output) | PV system (AC output) |
|----------------------------|-----------------------|-----------------------|
| EEI (EY per area)          | kWh m\(^{-2}\)        | kWh m\(^{-2}\)        |
| Energy yield estimation    | EN IEC 61 853-3       | Transitional methods  |
| Timeline simulation        | Year 1                | 30 years lifetime     |
| Elements                   | PV module             | PV array, inverter,   |
|                            |                       | and other BoS components |
| Degradation                | No                    | Yes                   |
| Losses                     | No\(^{(4)}\)          | Yes                   |
| Configuration              | Predefined            | User-defined inclination |
|                           | (incl. 20\(^{\circ}\), orient. south) | and orientation |

\(^{(4)}\)PV module intrinsic behavior considered.

ratio of generated end-use energy in proportion to the primary energy.\(^{(15)}\) 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 (e.g., the light emitted by a light bulb for a given amount of energy). In line with this rationale, the definition of “energy efficiency” within the Energy Labelling Regulation\(^{(4)}\) is “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\(^{(16)}\) from both the business-to-consumer and the business-to-business sectors, such as washing machines, dishwashers, household, commercial, and professional refrigerators, and ventilation units.

Despite the relevance of energy labels for energy-consuming products, the Energy Labelling Regulation clearly extends to all energy-related products. Article 2(1) of that regulation 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. However, when defining the “energy efficiency” of 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 at the beginning of this section, the “energy efficiency” of energy-generating products can be conceptually conceived as the generated end-use energy (which can be also considered as a proxy of the module/system performance) in proportion to the primary energy (which can be related to the solar energy received by the PV product), normalized per unit area. As a result 1) the energy label for PV modules could be based on the module EEI, which can be considered conceptually as a ratio between the electricity generated by the module over the course of the year under realistic operation conditions for each reference climate, normalized per unit area (module) and 2) the energy label for PV systems, i.e., installations, could be based on the conceptual ratio between the electricity generated by the installation throughout its (expected) lifetime for the relevant reference climate, normalized per unit area (system).

4.2. Why Energy Labels for PV Modules and Systems Are Needed

Ecodesign requirements and energy-labeling schemes are typically identified as the most effective solutions—in regulatory terms—to “market failures,” i.e., observed deviations from competitive market behavior from a sustainability and economic perspective.\(^{(17)}\) The market failures related to the proposals of energy-labeling schemes are typically linked to the problem of incomplete information accompanying the products, i.e., when customers are given neither sufficient quantity nor sufficient quality information about their purchase and behavior decisions. Energy labels are considered a reply to this problem, in that they help raise energy-use awareness with a straightforward message (the energy-labeling class), by means of ready-made calculation tools.

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 energy label for PV systems would aim to optimize and increase the energy yield of installations by enabling private individuals to make an informed choice based on the performance of designs, offered by retailers and installers, at the level of the whole system, i.e., taking into account not only the module type, but also the inverter, the geographical location, and the installation conditions. Installers and designers would in turn be free to develop designs and packages of system components and architectures that can improve the energy yield, and therefore improve the labeled rating of systems.

Because the PV module and PV system’s energy yield, modeled by the methods and methodology described in Section 2.2, are calculated taking into account these aspects, the energy label scheme could be based on this variable, normalized to the module area in the case of the PV module and to the PV array area in the case of the PV system. In both cases, the energy label scheme would be expressed in kilowatt hour per meter squared.

4.3. Proposed Energy Labels for PV Modules and Systems:
Energy-Labeling Classes and Label Design

A preliminary definition of the energy label classification for small PV systems based on the PV system energy efficiency index (EEIS) is shown in Table 2 for the three reference climates relevant for Europe, subtropical arid, temperate coastal, and temperate continental.\(^{(19)}\)

The preliminary energy label classification for PV modules, based on the module energy efficiency index (EEIM), is shown in Table 3 for the three reference climates relevant for Europe. The EEIM values that define the A to G labels for PV modules have been estimated considering modules of 26%
efficiency for the A/B threshold, 17% for the D/E threshold, and 13% for the F/G threshold. It should be noted here that the module efficiency is not the only parameter considered in the estimation of the module’s energy yield and EEIM because the climate-specific energy rating (CSER) parameter is also considered, as defined in the IEC 61853-3. The same module types have been considered for the estimation of the EEIS values used to define the thresholds of the A to G labels for the PV systems. In addition, specific inverter and system losses have been considered. Under this preliminary energy label classification, the A class initially is empty (i.e., it is unlikely to have nowadays residential installations featuring such a high EEIs value) to leave room for innovation and development of new, more energy-efficient products. At the same time, the A–G scale is intended to allow a broad range of performance. This is of particular importance for energy-generating products such as photovoltaics because all renewable energy produced contributes to the EU decarbonization target.

Figure 2 shows how the label for PV modules could actually look based on the methodology laid down in this article. The label in printed form would be provided by suppliers at the point of sale (including at trade fairs) and displayed in such a way as to be clearly visible. The label would be also displayed in any technical promotional material concerning a specific model of PV modules, including on the Internet.

In the upper half, the label would present the module energy efficiency class, defined based on the module energy efficiency index value, EEIM, as well as the EEIS value itself (i.e., the yearly energy generated by the PV module per module area), under “subtropical arid,” “temperate coastal,” and “temperate continental” reference climate conditions. It would be necessary to show the values related to all the three climatic areas as it would not be possible for the suppliers to know in advance the actual place of installation.

In the lower half, the label would display the reference EU map, giving a visual representation of the geographical distribution of the three reference climatic areas. On the left lower side, two more informative elements would be present, i.e., the lifetime performance degradation rate (represented with an icon...
featuring some histograms of decreasing height below an hourglass) and the PV module area.

5. Conclusion
A methodology to apply an energy-labeling scheme to both PV modules and small PV systems has been demonstrated. The estimated annual and lifetime yields of a PV module and system respectively (normalized to the corresponding PV area) can be used as parameters for classification from A to G in the proposed energy-labeling scheme. The article also elaborates on how to “translate” the methodology into an actual energy-labeling scheme, also discussing the conceptual challenges when referring to energy-generating products, i.e., PV modules and systems. This work, coupled with the preparatory activities on potential Ecodesign requirements, would lead to regulatory measures with a so-called push–pull effect on the market. That is, it would ensure that the worst-performing products cannot be placed on the EU market (through Ecodesign) and would empower consumers with a simple instrument for an informed choice of the most efficient products (through an A–G energy-labeling scheme). The proposed energy labels for PV modules and systems are expected to be a useful—and powerful—information tool for a number of stakeholders (installers, designers, private individuals), to properly factor in the “energy efficiency” of PV products.

Conflict of Interest
The authors declare no conflict of interest.

Data Availability Statement
The data that support the findings of this study are available from the corresponding authors upon reasonable request.

Keywords
energy labels, PV modules, PV performance

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[1] I. Kougias, N. Taylor, G. Kakoulaki, A. Jaeger-Waldau, Renew. Sustain. Energy Rev. 2021, 144, 111017.

[2] N. Dodd, M. D. L. N. Espinosa Martinez, P. Van Tichelen, K. Peeters, A. Soares, Preparatory Study for Solar Photovoltaic Modules, Inverters and Systems, https://publications.jrc.ec.europa.eu/repository/handle/JRC122431 (accessed: July 2008).

[3] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 Establishing a Framework for the Setting of Ecodesign Requirements for Energy-Related Products, OJ L285, 31.10.2009, p. 10–35, https://webstore.iec.ch/home.

[4] Regulation (EU)2017/1369 of the European Parliament and of the Council of 4 July 2017 Setting a Framework for Energy Labelling and Repealing Directive 2010/30/EU, OJ L198, 28.7.2017, p. 1–23, https://webstore.iec.ch/home.

[5] Standards for the Assessment of the Environmental Performance of Photovoltaic Modules, Power Conversion Equipment and Photovoltaic Systems, Publications Office of the European Union, 29247 EN, ISBN 978-92-79-86608-1, 2018, https://webstore.iec.ch/home.

[6] Transitional Methods for PV Modules, Inverters and Systems in a Ecodesign Framework, Publications Office of the European Union, 29513 EN. ISBN 978-92-79-98284-2, 2019.

[7] A. Jäger-Waldau, EPJ Photovoltaics 2021, 12, 2.

[8] M. Cordella, J. Sanfelix, F. Afferi, M. Bennet, Investigating Alignment and Potential Synergies on Circular Economy Requirements Between Sustainable Product Policy Instruments, JRC Technical Report, European Commission, Seville, 2018, JRC114333.

[9] European Commission, Discussion Paper on Potential Ecodesign Requirements and Energy Labelling Scheme(s) for Photovoltaic Modules, Inverters and Systems, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2021-04/Discussion%20paper%20Ecodesign%20Photovoltaic%20Products.pdf (accessed: July 2008).

[10] IEC 61853-4, Photovoltaic (PV) Module Performance Testing and Energy Rating – Part 4: Standard Reference Climatic Profiles, Edition 1.0, International Electrotechnical Commission 2018, https://webstore.iec.ch/home.

[11] IEC 61853-1, Photovoltaic (PV) Module Performance Testing and Energy Rating – Part 1: Irradiance and Temperature Performance Measurements and Power Rating, Edition 1.0, International Electrotechnical Commission 2011, https://webstore.iec.ch/home.

[12] IEC 61853-2, Photovoltaic (PV) Module Performance Testing and Energy Rating – Part 2: Spectral Responsivity, Incidence Angle and Module Operating Temperature Measurements, Edition 1.0, International Electrotechnical Commission 2016, https://webstore.iec.ch/home.

[13] IEC 61853-3, Photovoltaic (PV) Module Performance Testing and Energy Rating – Part 3: Energy Rating of PV Modules, Edition 1.0, International Electrotechnical Commission 2018, https://webstore.iec.ch/home.

[14] PV Enerate Project, https://www.euramet.org/research-innovation/search-research-projects/details/project/advanced-pv-energy-rating/?tx_eurametctcp_project%5Baction%5D=show&tx_eurametctcp_project%5Bcontroller%5D=Project&cHash=1ae99d1443c94d2e1801d21b98e59b9. (accessed: July 2008).

[15] W. Irrek, S. Thomas, Defining Energy Efficiency, Wuppertal Institute, http://wupperinst.org/uploads/tx_wupperinst/energy_efficiency_definition.pdf (accessed: July 2008).

[16] https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-ecodesign/energy-efficient-products_en (accessed: July 2008).

[17] V. Bukarica, Z. Tomišić, Renew. Sust. Energy Rev. 2017, 70, 968.
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