Technical definitions for a Potential Energy Label for PV Modules and Systems

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Joint Research Centre

Agenda

09:30 Welcome D. Polverini

09:50 1. Introduction E. Dunlop

10:00 2. Definition of Energy Efficiency Indexes (EEI) for PV Modules A. Gracia Amillo

10:25 3. Definition of Energy Efficiency Indexes (EEI) for PV Systems A. Gracia Amillo

10:45 4. Modified method for defining System Losses for PV system EEI estimation and classification E. Dunlop

11:00 Discussion followed by 10 min break

11:20 5. Input requirements for EEI estimation and classification for PV Modules and PV Systems A. Gracia Amillo

11:35 6. Granularity and sensitivity of proposed Energy Label for PV Modules and PV Systems E. Dunlop

11:50 Additional Information

12:05 Discussion and Conclusions

End of Meeting

Background – Preparatory Study

Welcome

The JRC study – Q4 2017- Q4 2019

Concept:
ONE research process for different policies

- Ecodesign minimum Requirements?
- Energy Label classes?
- Ecolabel criteria?
- GPP criteria?

The results: a policy mix with
Mandatory instruments + Green Public Procurement

Environmental impacts of PV products

- Stakeholder meeting in November 2020.
- Two initiatives on the 'environmental impact of photovoltaics' encoded in 'have your say' (publication of the IIA expected in April 2021).
- Expert Input paper of the Joint Mission Group, February 2021.
- Technical meeting March 25th 2021.
- Stakeholder meeting 29th April 2021.

Environmental impacts of PV products

Aim of the meeting today:

1. Present and discuss some updates on the work for testing and calculation methods in support of potential Energy scheme(s) for PV modules and systems
2. Synergy with the 29th April meeting

Today: focus on technical aspects

Technical definitions for a Potential Energy Label for PV Modules and Systems

1. Introduction

- **Energy Labelling Regulation EU 2017/1369:**

"Framework" defining the "rules" for setting product-specific requirements/legislation on standard information of the consumption of energy and other resources to promote increased energy efficiency in products available in the EU market.

- Proposal to implementation the Energy Label to PV modules and small PV systems.
- Label classification based on Energy Efficiency Index (EEI).
- PV modules and systems improve "energy efficiency" in proportion to their energy yield. Therefore this is the basis for the EEI.

1. Introduction.

- Energy label

“the proposed Energy Labelling schemes for PV modules and systems have specific features, when compared to products already regulated with an energy label, as they would target energy generating products”.

- Energy Efficiency Index

“‘energy efficiency’ within the Energy Labelling Regulation 2017/1369: ‘the ratio of output of performance, service, goods or energy to input of energy’.
So far, this approach has been successfully applied to a wide range of energy using products from both the business-to-consumer and the business-to-business sectors, such as washing machines, dishwashers, household, commercial and professional refrigerators, ventilation units”. We will define this unit as the EEI.

1. Introduction. Scope

PV modules:

- individual modules products placed on the EU market and intended for use in photovoltaic systems for grid-connected electricity generation.

PV systems:

- Small Systems with installed peak power less than or equal to 20 KWp

  e.g. Residential, small commercial, agricultural systems, etc.

1. Introduction. Scope

PV modules: Exclusions

- Photovoltaic Modules with a DC output power of less than 50 Watts under Standard Test Conditions (STC).
- Photovoltaic modules used as construction products (building integrated photovoltaics) i.e. providing a function as defined in the European Construction Product Regulation CPR 305/2011. *
- Customized module designs intended for specific static or mobile applications or integrated into consumer electronic products.

Special considerations :

- For modules containing micro-inverters integrated/embedded, the modules and inverters should be labelled or characterised in accordance to the Ecodesign and Energy label regulation before the integration occurs.
- PV modules that are intended for BIPV use but are not tailor-made modules/inverters, have to fulfil the requirements.
- PV modules manufactured with new technologies that initially enter the market, with the aim of not dissuading innovation.

* Building added PV products are in scope unless excluded by other criteria specified here.

Questions - Introduction

1. Introduction

2. Definition of Energy Efficiency Index (EEI) for PV Modules

3. Definition of Energy Efficiency Indexes (EEI) for PV Systems
4. Modified method for defining System Losses for PV system EEI estimation and classification
5. Input requirements for EEI estimation and classification for PV Modules and PV Systems
6. Granularity and sensitivity of proposed Energy Label for PV Modules and PV Systems

2.1. PV modules EEI proposal

Energy yield per module area (kWh/m²)

- Energy yield calculated according to EN IEC 61853-3.
- One year simulation.
- Climatic conditions defined in EN IEC 61853-4:

"Subtropical arid", *"Temperate coastal"* and *"Temperate continental"*

- PV module installation: ground mounted, fixed open-rack, South facing and 20º inclination.
- Degradation and losses NOT considered.
- Ground albedo and surrounding obstacles NOT considered.

2.2. Bifacial PV modules EEI proposal

Energy yield per module area (kWh/m²)

- No standards available for bifacial modules energy yield estimation.
  - ➢ IEC TC82 to consider a work item on extending IEC 61853.
  - ➢ EU "*PV Enerate*" project defined requirements to extend IEC 61853 to bifacial modules.
- One year simulation.
- Climatic conditions defined in EN IEC 61853-4:

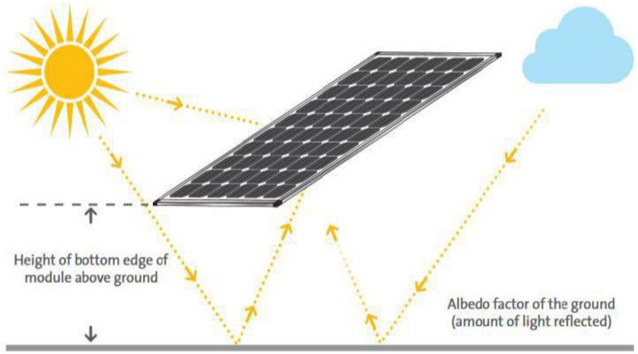
"Subtropical arid", "Temperate coastal" and *"Temperate continental"*

- Degradation and losses NOT considered.

2.2. Bifacial PV modules EEI proposal

"*PV Enerate*" proposal for IEC 61853 extension to bifacial modules

- New PV module input data:
  - bifaciality, IEC TS 60904-1-2 (2019)
  - BNPI (IEC EN 61215-1 (2021))
  - power matrix (standard not available)
- New climatological datasets referred to new installation configurations
- Modified models for estimation of:
  - in-plane irradiance (including albedo),
  - energy yield



Extension of energy rating to bifacial modules – proposals from the PV-Enerate projects (JRC122448)

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2.3. Monofacial and bifacial example

	Subtropical arid		Temperate coastal	
	Monofacial	Bifacial(*)	Monofacial	Bifacial(*)
Climate Specific Energy Rating (CSER)	0.904	0.847	0.982	0.93
EEI (kWh/m^2)	357.136	443.085	164.357	210.845

Installation

Ground mounted, South facing, inclination 20º

Albedo for bifacial modules of 20%

Module characteristics

	PSTC (W)	BNPI (W)	Efficiency (%)	Area (m^2)	Bifaciality (%)
Monofacial	280.46	-	17.21	1.63	-
Simulated bifacial (*)	-	314.54	19.30	1.63	90

(*) Simulated bifacial module, based on the monofacial module with 90% bifaciality

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Questions – EEI for PV Modules

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3.1. PV Systems EEI proposal

Energy yield per system area (kWh/m^2)

- Energy yield calculated according to transitional methods, partly based on EN IEC 61853-3.
- 30 years lifetime simulation.
- Climatic conditions defined in EN IEC 61853-4:

"Subtropical arid", "Temperate coastal" and *"Temperate continental"*

- User defined PV array's inclination and orientation angles.
- Degradation, system losses and surrounding obstacles considered.
- Ground albedo NOT considered.

STEP 1

PV array **DC annual** energy output

EN 61853

Year 0

STEP 2

Inverter **performance**

Transitional method + EN 50530

STEP 3

PV system **losses**

Transitional method

STEP 4

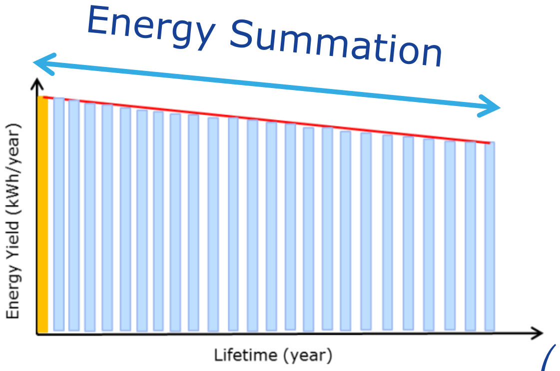
PV array **AC annual** energy output

Transitional method

STEP 5

PV array **AC LIFETIME** energy output

Transitional method



Degradation

Lifetime

$$System\ EY_{AC\_lifetime} = System\ EY_{AC\ year\ 0} \cdot T_{lifetime} \cdot \left(1 - \tau_{deg} \cdot \frac{T_{lifetime}}{2}\right)$$

3.2. EEI for PV module vs. EEI for PV Systems

	PV module	PV system
EEI (EY per area)	kWh/m^2	kWh/m^2
Energy yield estimation	EN IEC 61853-3	Transitional methods
Area	Module	PV array
Timeline simulation	Year 1	30 years lifetime
Elements	PV module	PV array, Inverter and other BoS components
Degradation	No	Yes
Losses	No (*)	Yes
Configuration	Predefined (incl. 20º, orient. South)	User defined inclination and orientation

(*) PV module instrinsic behaviour considered

Questions – EEI for PV systems

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Short Break restart at 10:50

1. Introduction
2. Definition of Energy Efficiency Index (EEI) for PV Modules
3. Definition of Energy Efficiency Index (EEI) for PV Systems
4. **Modified method for defining System Losses for PV system EEI estimation and classification**
5. Input requirements for EEI estimation and classification for PV Modules and PV Systems
6. Granularity and sensitivity of proposed Energy Label for PV Modules and PV Systems

4.1 Previous method for System Losses definition

PV system losses: default values or user defined values, according to some restrictions

Use default values (Y/N)	N	Insert estimated losses in User values (%)				
		Defined losses cannot be lower than Minimum values				
Losses	Default values (%)	Minimum values (%)	Typical values (%)	Average values (%)	User values (%)	Applied values (%)
Module mismatch	3.00	1.50	2.00	1.75	1.80	1.8
DC wiring	3.00	1.00	2.00	1.50	3.00	3
Diodes and connectors	1.00	0.30	0.50	0.40	0.50	0.5
Soiling	25.00	2.00	5.00	3.50	6.00	6
Shading	10.00	0.10	5.00	2.50	4.50	4.5
AC wiring	2.00	0.70	1.00	0.85	0.85	0.85
Inverter temperature derating	1.80	0.10	1.00	0.55	1.50	1.5
…						
…						
…						
	38.26					16.19

MODIFIED

Not verifiable by surveillance authorities

PV system losses used in the calculations

Default PV system losses, worst case scenario

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4.2. Modified approach for System Losses definition

- Declared losses must be verifiable by surveillance authorities. Therefore, independent of maintenance and operation activities.
- Proposed losses values defined to obtain PV system's performance ratio (PR) aligned with European average values observed for 25434 systems across Europe over a 5 year period.

  Average PR 0.73 ± 0.09
- System losses (%) = $100 \cdot [1 - (\prod_{i=1}^{n}(1 - 0.01 \cdot Lf_i))]$

  Lf_i Loss factor i (%)

https://doi.org/10.1016/j.solener.2021.02.001

4.2. Modified approach for System Losses definition

- Two components:
  - Fixed baseline losses: non-verifiable
  - Variable losses derived from:
    - PV system elements: PV module *(CSER* effects), inverter, storage
    - PV system installation and configuration:
      - inclination and orientation of PV array
      - presence of nearby obstacles
      - presence of very dusty or polluted environment
      - non-optimal configuration

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4.2. Modified approach for System Losses definition

- Baseline losses are always applied. For example, 10%-14%.
- Variable losses estimated based on questionnaire and default values

1. Question 1. Is something shading the system within 10m of the system (local building or garden issues such as chimneys, antenna, small trees etc.)
   - **yes then -3%**
2. Question 2. Is something shading beyond 10m from the system (yes then -3%) (buildings large trees etc.)
   - **yes then -3%**

4.2. Modified approach for System Losses definition

3. Question 3. Is there significant horizon sun blocking such as hills or mountains (Land scape issues)
   - **yes then -3%**
4. Question 4 .Is there any other significant exceptional loss factors
   a) A difficult or extensive wiring (for example array greater than 10m* from Inverter **Yes then -2%**
   b) Particularly polluting or dusty environment such as vicinity to polluting industrial area… **Yes then -2%**
   c) Other factor such as physical separation of array with or without different orientation… **Yes then -2%**

* To be verified

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4.3. Example PV System Losses definition

PV System PR values after losses (baseline + installer-declared)

	Subtropical arid		Temperate coastal		Temperate continental	
Losses	Min	Max	Min	Max	Min	Max
Baseline 10%	80.11	68.81	84.74	72.80	82.81	71.13
Baseline 14%	76.55	65.76	80.98	69.56	79.13	67.97

Minimum losses = module and inverter losses + fixed baseline component

Maximum losses = module and inverter losses +

fixed baseline component plus all variable components

Questions – PV systems losses definition

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5.1. Input requirements for EEI estimation and PV Module classification

- Pmax STC (W) , BNPI for Bifacial
- Module's area (m^2)
- *Climate Specific Energy Rating, CSER* (EN IEC 61853 standard) for three European reference climates

$$EEI_m = \frac{EY_m\ (kWh)}{A_m\ (m^2)} = \frac{CSER \cdot P_{STC}(W) \cdot H_p\ (\frac{kWh}{m^2})}{1000\left(\frac{W}{m^2}\right) \cdot A_m\ (m^2)}$$

5.2. Input requirements for EEI estimation and PV System classification

- PV module:
  - Number of PV modules
  - Pmax STC (W), BNPI for Bifacial
  - Module's area (m^2)
  - *Climate Specific Energy Rating, CSER* (EN IEC 61853 standard) for three European reference climates
  - Degradation rate (%)

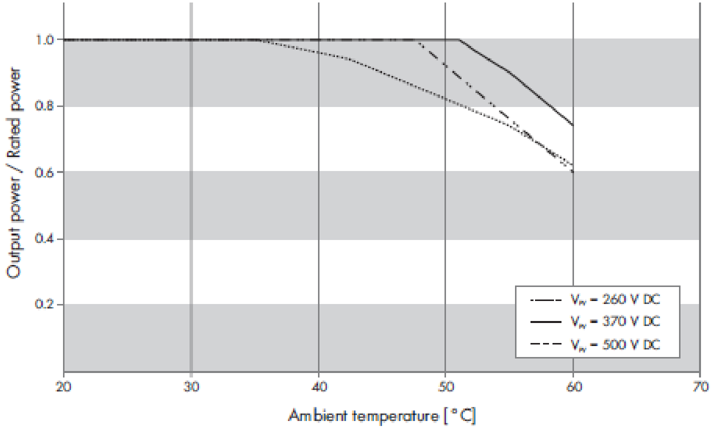
5.2. Input requirements for EEI estimation and PV System classification

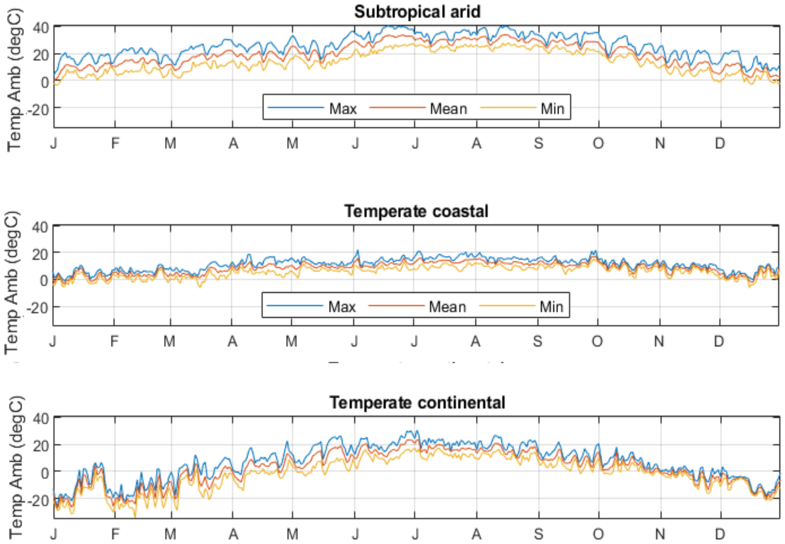
- Inverter:
  - Microinverter (Y/N)
  - AC rated power (kW)
  - *Euroefficiency* (%)
  - Temperature derating factor (%)
    - Proposed method based on declared temperature threshold above which derating occurs and inverter installation environment (EN 50524)
    - EN IEC 61853-4 temperature profile

5.2. Input requirements for EEI estimation and PV System classification

EN 50524 Inverter operating conditions (pr EN 62093 in draft)

- unprotected in the open
- protected in the open
- air-conditioned in interiors
- without air-condition in interiors





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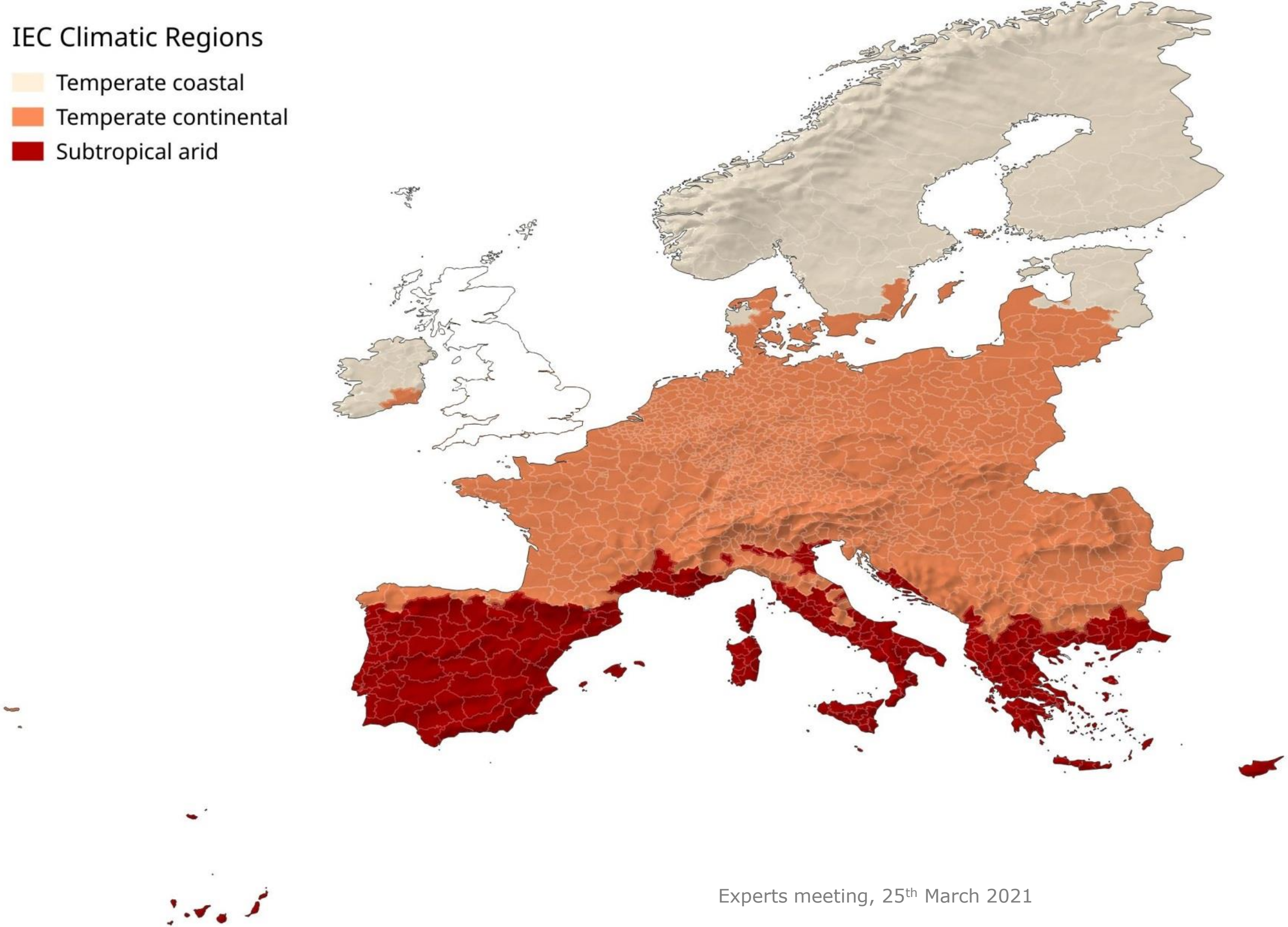
5.2. Input requirements for EEI estimation and PV System classification

- PV system installation and configuration:
  - PV array inclination
  - PV array orientation
  - PV system losses
  - Location’s NUTS 3 region

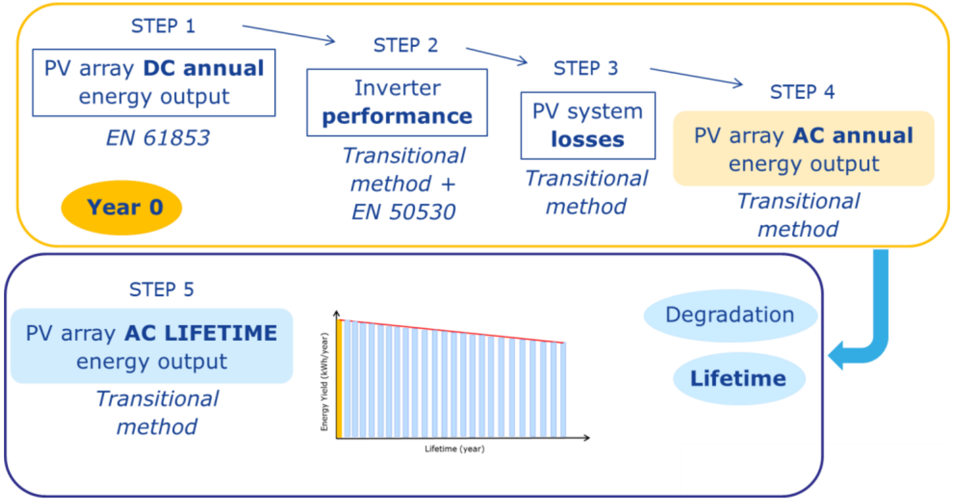
5.2.



Disclaimer:
Regulation to be applied in EU and EFTA countries only

5.2. Input requirements for EEI estimation and PV System classification

$$EEI_s = \frac{EY_s\ (kWh)}{A_s\ (m^2)} = \frac{f(PV\ m, Inv, Losses, LF, Deg, Conf, Loc)}{A_s\ (m^2)}$$



PV module (monofacial or bifacial)
BAPV de-rating factor
Inverter
PV system losses
Lifetime
Degradation
Configuration and Installation
Location (relevant climate)

Questions – Input requirements

6. Granularity and sensitivity of proposed Energy Label for PV Modules and PV Systems

6.1. Granularity of proposed Energy Label for PV Modules

	Module Energy Efficiency Index (kWh/m²)		
Energy Label	Subtropical arid	Temperate coastal	Temperate continental
A	> 566	> 257	> 330
B	[566 - 496)	[257 - 226)	[330 - 291)
C	[496 - 426)	[226 - 195)	[291 - 252)
D	[426 - 356)	[195 - 164)	[252 - 213)
E	[356 - 310)	[164 - 140)	[213 - 182)
F	[310 - 265)	[140 - 117)	[182 - 151)
G	≤ 265	≤ 117	≤ 151

Threshold for **A label** defined by:
- 430.8 Wp
- 26% eff PV module

Threshold for **D label** defined by:
- 281.7 Wp
- 17% eff PV module

Threshold for **F label** defined by:
- 215.4 Wp
- 13% eff PV module

6.1. Granularity of proposed Energy Label for PV Modules. Example

Following previous example for monofacial and bifacial modules

Location in Subtropical arid climate

- Monofacial device
  - EEI (kWh/m^2): 357.136
  - Energy label: D
- Simulated bifacial device
  - EEI (kWh/m^2): 443.085
  - Energy label: C

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

6.2. Granularity of proposed Energy Label for PV Systems

	PV System Energy Efficiency Index (kWh/m²)		
Energy Label	Subtropical arid	Temperate coastal	Temperate continental
A	> 13974	> 6388	> 8232
B	[13974 - 11659)	[6388 - 5343)	[8232 - 6899)
C	[11659 - 9345)	[5343 - 4298)	[6899 - 5566)
D	[9345 - 7031)	[4298 - 3253)	[5566 - 4233)
E	[7031 - 6076)	[3253 - 2766)	[4233 - 3589)
F	[6076 - 5122)	[2766 - 2279)	[3589 - 2946)
G	≤ 5122	≤ 2279	≤ 2946

Threshold for **A label** defined by:
- 26% eff PV module
- 100% Euroefficiency inverter
- 10% PV system losses

Threshold for **D label** defined by:
- 17% eff PV module
- 98% Euroefficiency inverter
- 22.7% PV system losses

(worst case scenario)

Threshold for **F label** defined by:
- 13% eff PV module
- 96% Euroefficiency inverter
- 22.7% PV system losses

(worst case scenario)

6.2. Granularity of proposed Energy Label for PV Systems. Example

Location in Subtropical arid climate

PV system:

- Inclination: 20º
- Orientation: South
- Installed Peak Power: 3.84 kWp
- Module efficiency: 19.3%
- Euroefficiency: 95%
- PV system losses: 14.8%
- Degradation: 1%

➢ EEI (kWh/m^2): 8042
➢ Energy Label: D

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

Questions – Granularity definition

Thank you for your attention

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