THE EU ECODESIGN DIRECTIVE

Methodology Analysis and Implications for PV Module Manufacturers

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Methodology Analysis for the EU Ecodesign Directive

Agenda

- Ecodesign Directive for Photovoltaic Modules
- Methodology
- Scenario Analysis
- Results and Observation
  - Electronic Product Environmental Assessment Tool (EPEAT)
  - Product Environmental Footprint Category Rules (PEFCR) (Adaptation for Ecodesign)
- Discussion
- Conclusion

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Ecodesign DIRECTIVE 2009/125/EC of the European Parliament

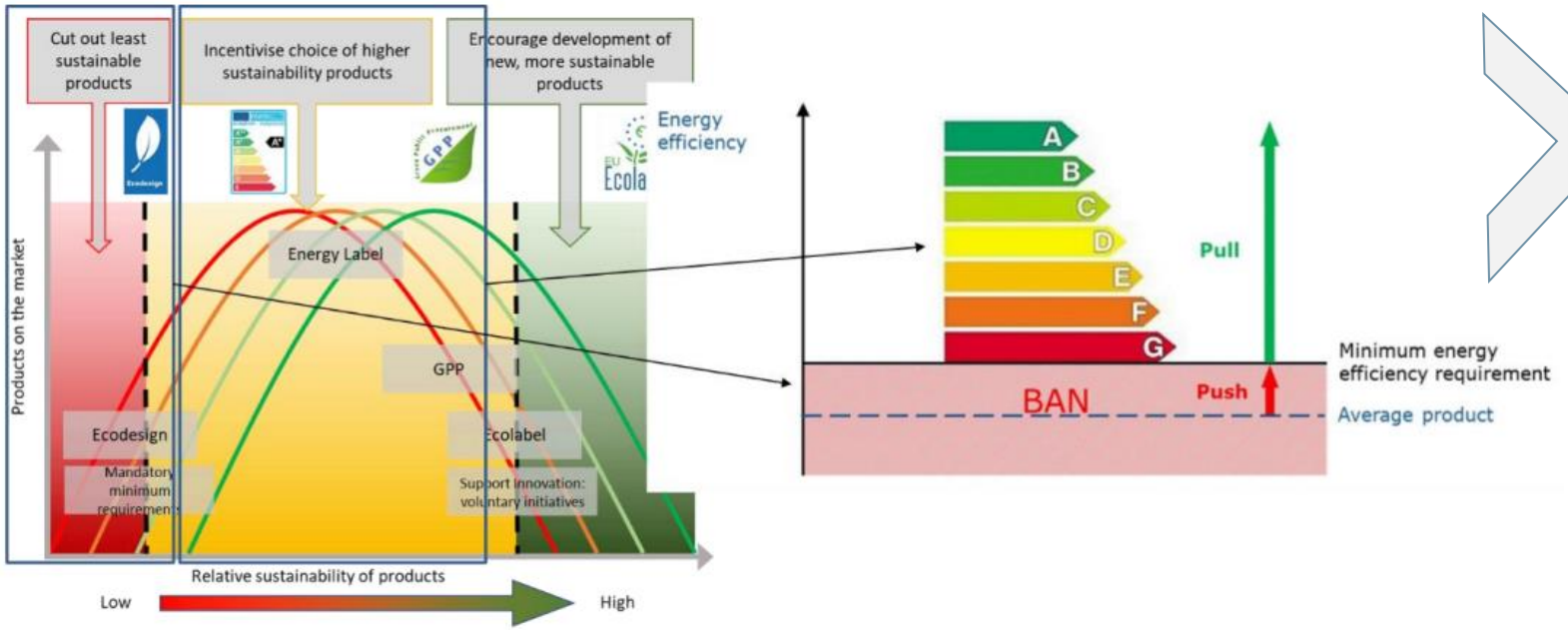
Objective

Mandatory **carbon footprint label** for photovoltaic modules belonging to the categories:

i. Multicrystalline Silicon photovoltaic modules (multi-Si)

ii. Monocrystalline Silicon photovoltaic modules (mono-Si)

iii. Cadmium-Telluride photovoltaic modules (CdTe)



The goal of Ecodesign directive can be:

- Minimized Green-Washing Scope [2]
- Comparable Labels [3]
- Market Entry Regulation [1,3]

*1

1. ETIP PV, SolarPower Europe, PVthin, European Solar Manufacturing Council, IECRE, Eco-Design and Energy Labeling for Photovoltaic Modules, Inverters and Systems – Enabling a Sustainable Value Chain in the EU?, 2021.
2. Arbinolo R., EU Commission prepares to crack down on greenwashing with new Green Claims law, The European Environmental Bureau, 2023.
3. Davide Polverini, Nieves Espinosa, Umberto Eynard, Enrica Leccisi, Fulvio Ardente, Fabrice Mathieux, Assessing the carbon footprint of photovoltaic modules through the EU Ecodesign Directive, Solar Energy, Volume 257, 2023, Pages 1-9, ISSN 0038-092X, https://doi.org/10.1016/j.solener.2023.04.001.

Motivation

- Ecodesign directive will be mandated for all electronic products within EU.
- Photovoltaic (PV) modules expected in the EU market → **320 GW by 2025** and ~**600 GW by 2030.** [1]

❖ It is important to ensure if the methodology chosen for this directive can achieve the desired goal.

Life cycle assessment (LCA) conducted on the same PV module using methodologies:

1. Electronic Product Environmental Assessment Tool (EPEAT) [2]
2. Ecodesign adaptation of Product Environmental Footprint Category Rules (PEFCR) [3]

This analysis highlights where

1. each of the methodologies fail to fulfill the goals of Ecodesign and
2. the EU PV manufacturers are vulnerable or at a disadvantage.

➢ **Aim:** Enable EU Commission policy makers and European PV manufacturers visualize the pros and cons of choosing one over another and stimulate discussions.

1. EU Solar Energy Strategy (2022), Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions.
2. Green Electronics Council dba Global Electronics Council (GEC), EPEAT (2023), Criteria for the Assessment of Ultra-Low Carbon Solar Modules.
3. First Solar Proprietary (2020), Product Environmental Footprint Category Rules (PEFCR), Photovoltaic modules used in photovoltaic power systems for electricity generation, Version: 1.2.

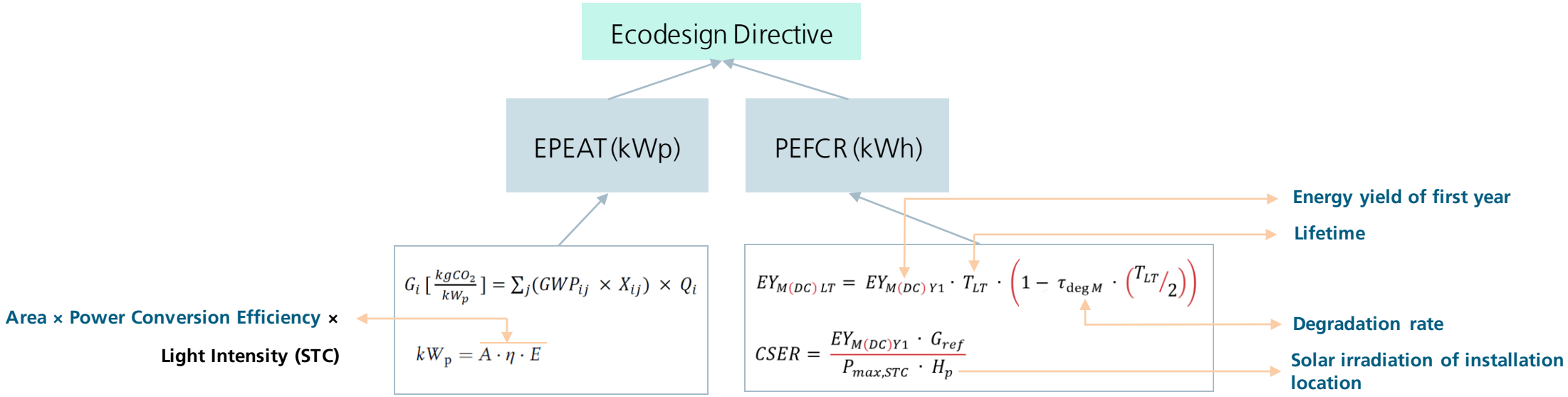
Methodology Comparison

EPEAT vs. PEFCR (Ecodesign adaptation)

Global warming potential (GWP) or carbon footprint can be calculated through different impact assessment methods:

- **PEFCR:** IPCC 2013 GWP 100a
- **EPEAT:** IPCC 2013 GWP 100a or later

Calculation method:

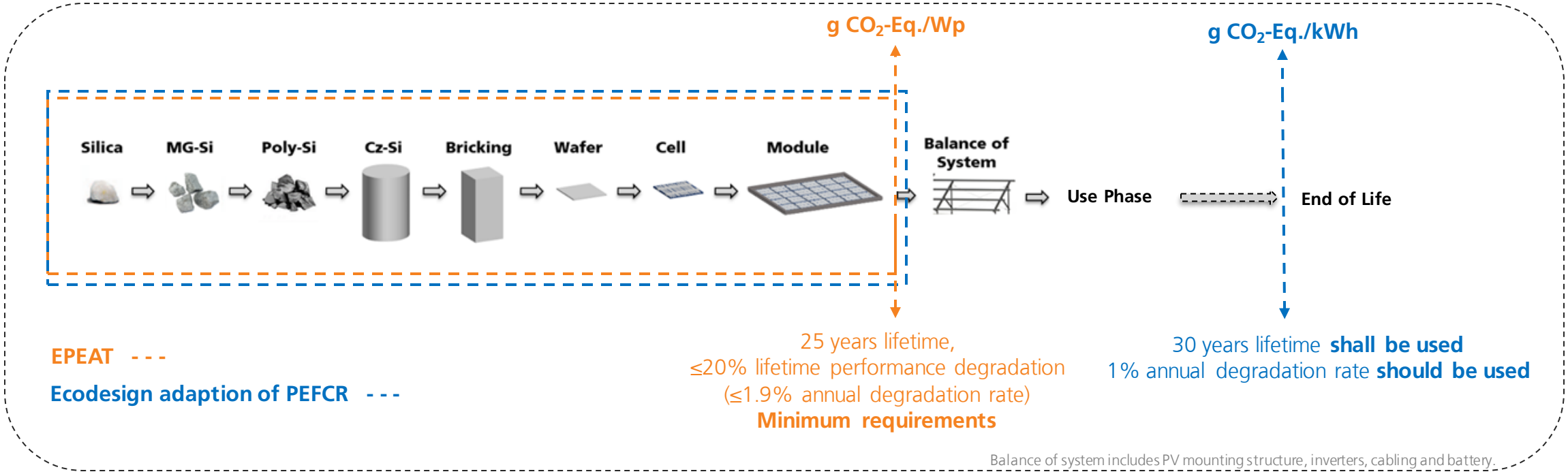


System Boundary

EPEAT vs. PEFCR (Ecodesign adaptation)

System Boundary: Cradle-to-gate (i.e. till module)

Functional Unit: EPEAT: g CO_2-Eq./kWp,
PEFCR (Ecodesign adaption): g CO_2-Eq./kWh



Methodology

EPEAT vs. PEFCR (Ecodesign adaptation)

- **Technology used:** p-type M6 (Cz-Si) wafer and Passivated Emitter and Rear Contact (PERC) PV module [1]
- **LCA methodology:** ISO standards 14040-4 [2, 3], IEA PVPS 12 'Methodology Guidelines for LCA on PV' [4]
- **Database:** Ecoinvent 3.8 database [5]
- **Software:** Umberto 11 [6]

1. Khan et al., (2023) Global warming potential of photovoltaics with state-of-the art silicon solar cells: Influence of electricity mix, installation location and lifetime. Submitted.
2. ISO 14040 (2009) Environmental management – Life cycle assessment – Principles and framework., 2009-11
3. ISO 14044 (2006) Environmental management – Life cycle assessment – Requirements and guidelines., 2006-10
4. Frischknecht, R.P. Stolz, G. Heath, M. Raugei, P. Sinha, and M. de Wild-Scholten (2020) Methodology Guidelines on Life Cycle Assessment of Photovoltaic 2020: Task 12-18
5. Wernet G, Bauer C, Steubing B, Reinhard J, Moreno-Ruiz E, Weidema B (2016) The ecoinvent database version 3 (part I): overview and methodology. Int J Life Cycle Assess 21(9):1218–1230. doi:10.1007/s11367-016-1087-8
6. Hamburg: ifu Institut für Umweltinformatik Hamburg GmbH Umberto 11

Scenario Assumptions

EPEAT vs. PEFCR (Ecodesign adaptation)

EPEAT (GWP in g CO_2-Eq./Wp):

Sensitivity analysis of GWP to

1. Module peak power (Wp)
2. Production electricity mix and share of Power Purchase Agreement (PPA) used.

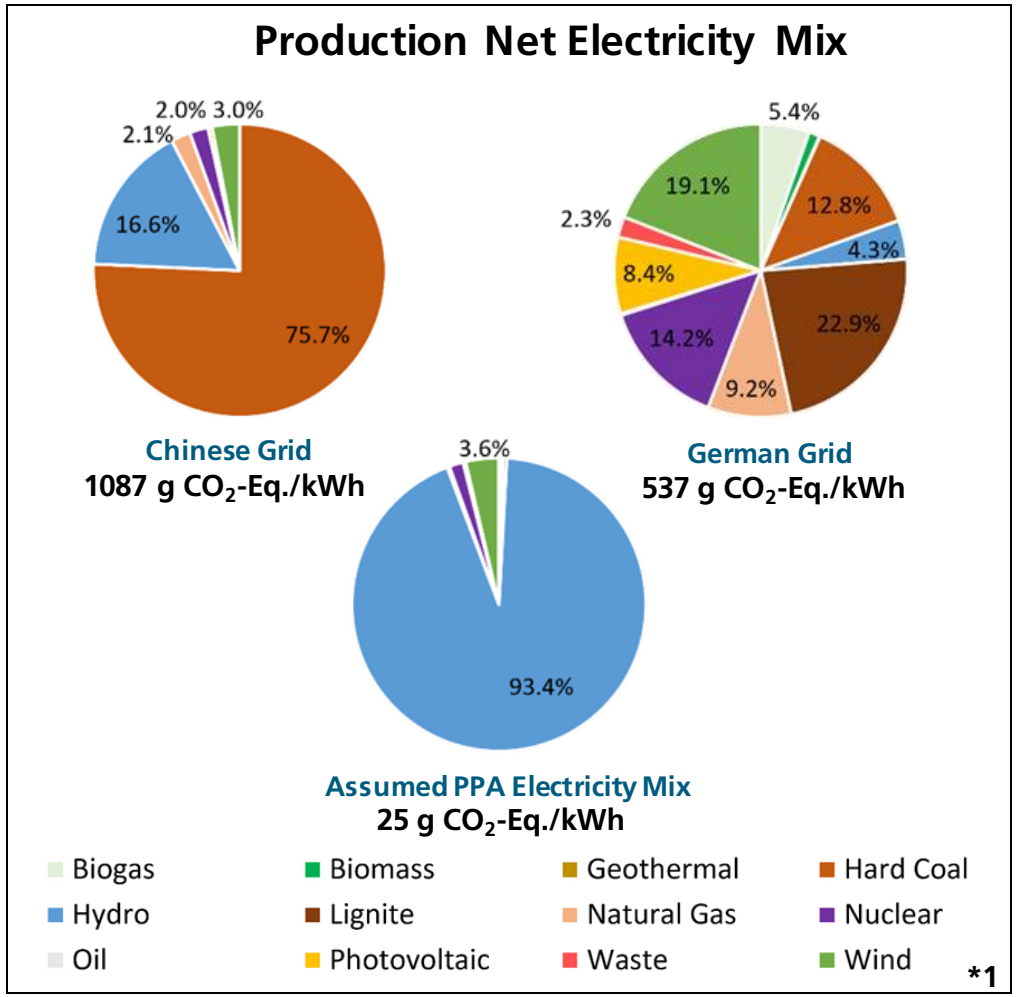
PEFCR (GWP in g CO_2-Eq./kWh):

Sensitivity analysis of GWP to

1. Module peak power (Wp) or module efficiency (%)
2. Module lifetime (years)
3. Module degradation rate (%/year)
4. Production electricity mix and share of Power Purchase Agreement (PPA) used.

Upstream: Production Electricity Mix

Composition and Carbon Footprint



To show a wide range of carbon footprint, the net electricity mix used for production is categorized into three:

1. High Fossil Share (HFS) Electricity Mx

China 1087 g CO_2-Eq./kWh

India 1491 g CO_2-Eq./kWh

Poland 1035 g CO_2-Eq./kWh

Malaysia 839 g CO_2-Eq./kWh

2. Moderate Fossil Share (MFS) Electricity Mx

Germany 537 g CO_2-Eq./kWh

USA 514 g CO_2-Eq./kWh

Portugal 414 g CO_2-Eq./kWh

Average European 392 g CO_2-Eq./kWh

Italy 392 g CO_2-Eq./kWh

Spain 329 g CO_2-Eq./kWh

3. Assumed Power Purchase Aggreement (PPA) Electricity Mx

PPA 25 g CO_2-Eq./kWh

1. Khan et al., (2023) Global warming potential of photovoltaics with state-of-the art silicon solar cells: Influence of electricity mix, installation location and lifetime. Submitted.

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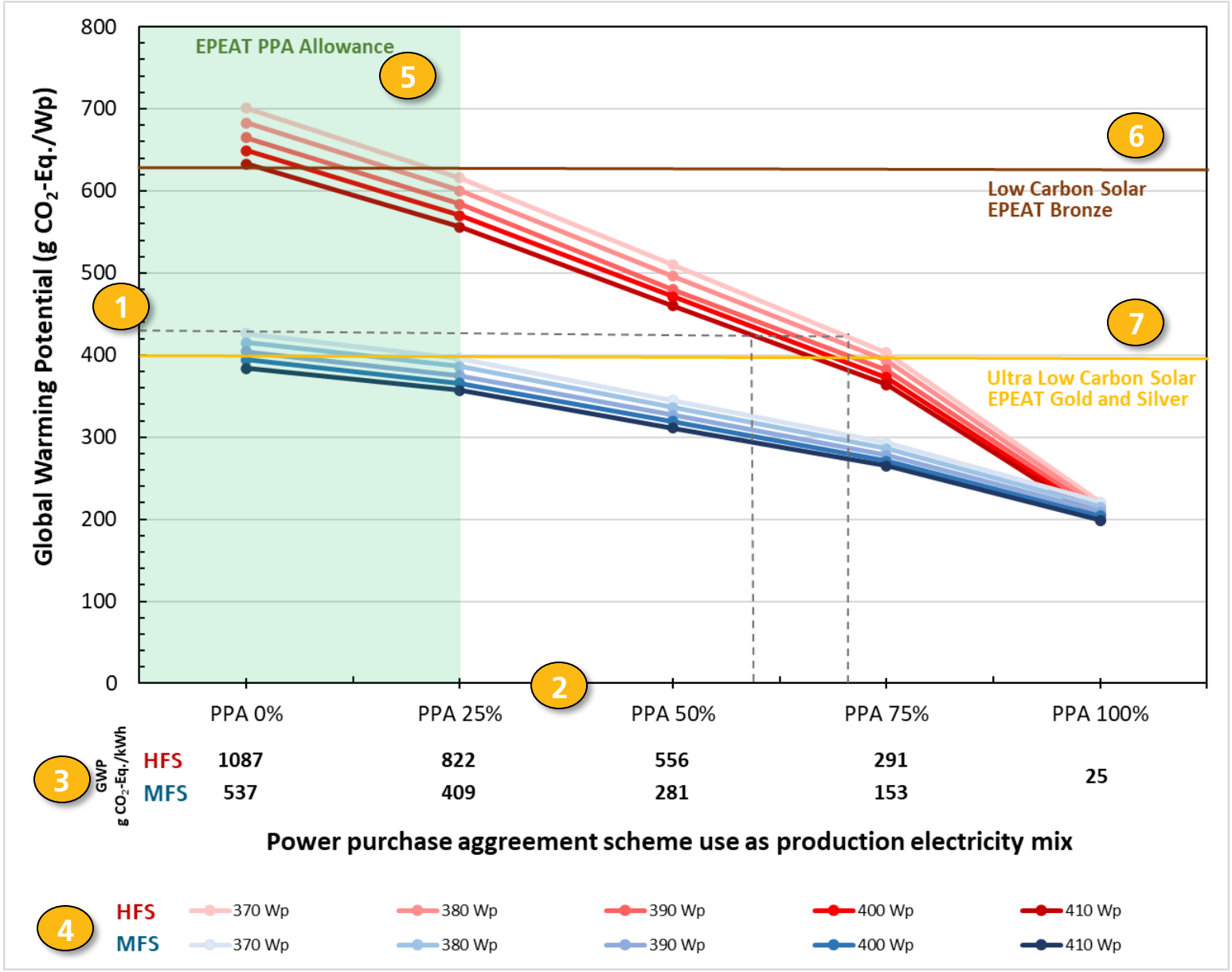
RESULTS AND OBSERVATIONS

EPEAT
Diagram Orientation

1. Y-axis: GWP/Wp
2. X-axis: PPA allowance
3. GWP/kWh of electricity mix
4. Module production location and peak power
5. PPA allowance in EPEAT
6. EPEAT Bronze requirement
   630 g CO_2-Eq./Wp (Required)
7. EPEAT Gold and Silver requirement
   400 g CO_2-Eq./Wp (Optional)



HFS: High Fossil Share; MFS: Moderate Fossil Share; PPA: Power Purchase Agreement

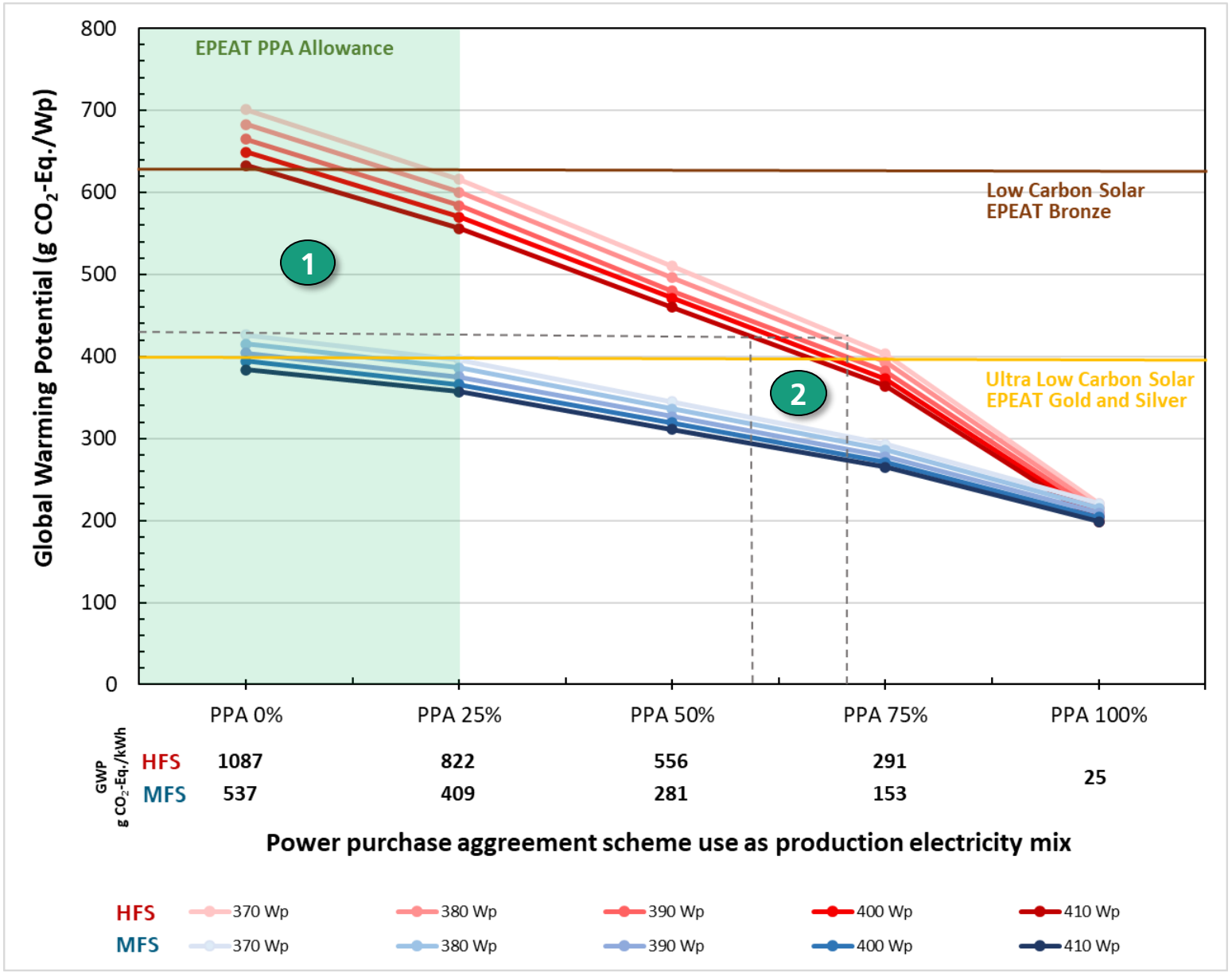
EPEAT

Observations

1. The **25% PPA allowance limit** benefits manufaturers located in a region of moderate and low fossil electricity grids.
   - ➢ Creates stong motivation for the high fossil share grids to decarbonise.

2. With the assumed PPA, manufacturers with a high fossil share national grid need at least *~60% PPA* to break-even with the moderate german grid.

3. **Simplified calculations -** does not involve relying on certificates for parameters such as *lifetime* and *degradation rate*.



HFS: High Fossil Share; MFS: Moderate Fossil Share; PPA: Power Purchase Agreement

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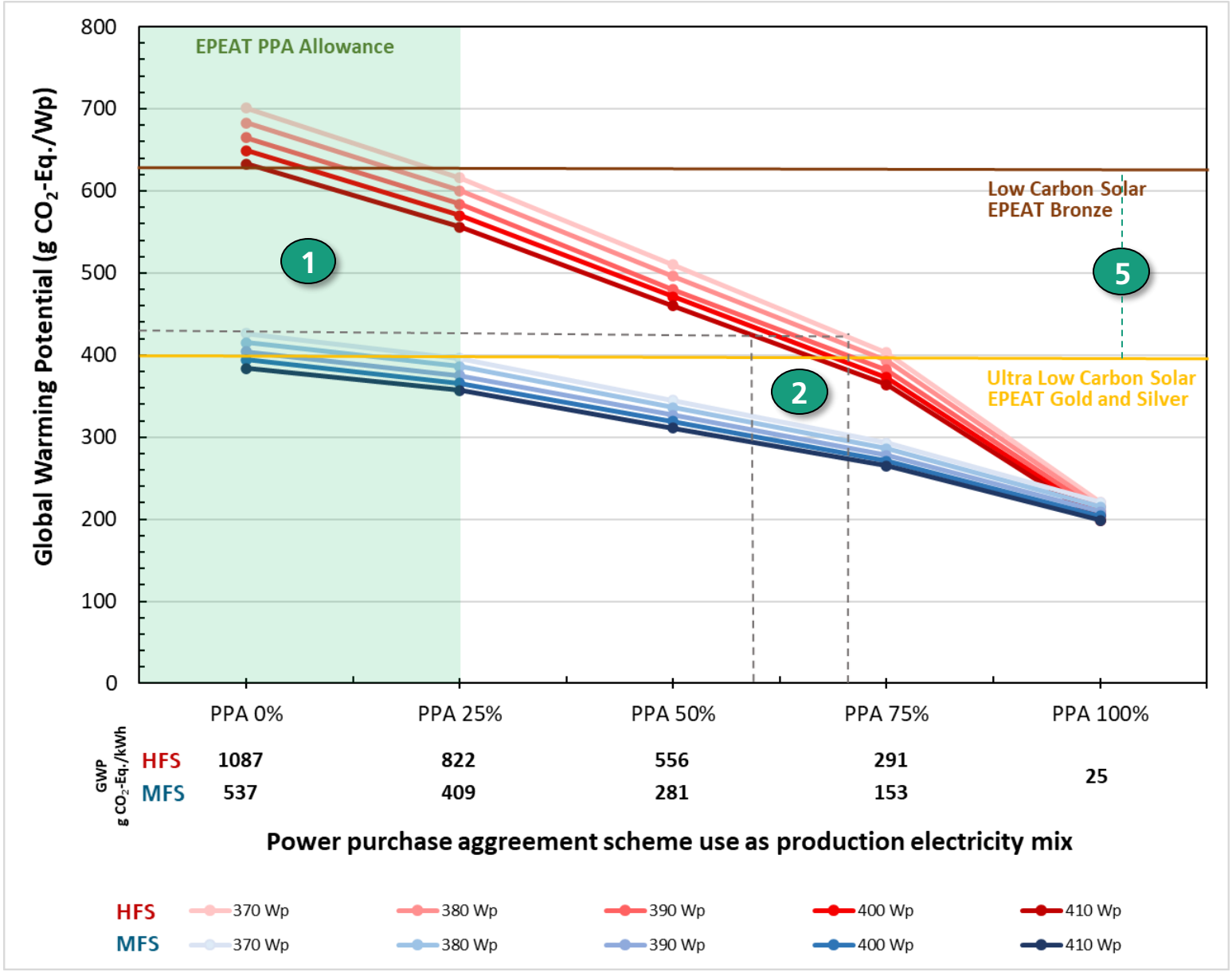
EPEAT
Observations

4. Global scale label

- EPEAT methodology is the basis of the Global Ecolabel.
- Cost+time saving opportunity if Ecodesign also follows EPEAT.
- Level playing field achieved for EU manufactured modules compared to the imported modules which currently do not pay carbon tax.

5. Potential market entry limit for Ecodesign **could be adjusted** and different to e.g. EPEAT bronze limit.



HFS: High Fossil Share; MFS: Moderate Fossil Share; PPA: Power Purchase Agreement

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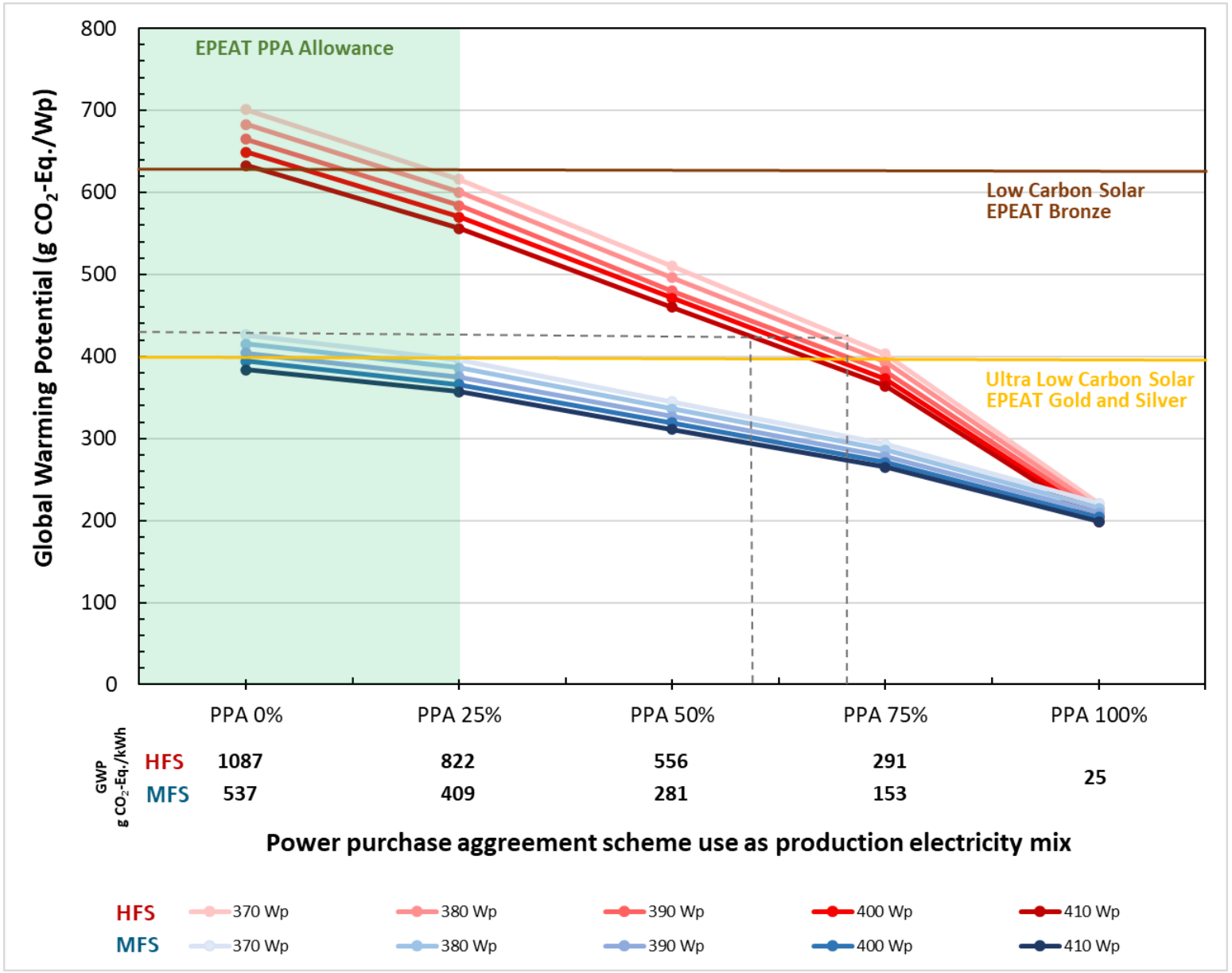
EPEAT
Observations

6. **Lifetime and Degradation not accounted** as carbon foortprint of module only upto the market is intended to be shown.

➢ **Minimum requirements set**: 25 year lifetime and less than 20% performance degradation over lifetime.



HFS: High Fossil Share; MFS: Moderate Fossil Share; PPA: Power Purchase Agreement

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EPEAT
Observations

6. **Lifetime and Degradation not accounted** as carbon foortprint of module only upto the market is intended to be shown.
   - Categorizes 450 Wp 25 y warranty LT modules and 450 Wp 40 y warranty LT modules as same.
   - Does not incentivize LT and DR improvement through R&D.
   - Overall kWh footprint needs to be calculated by customer based on provided LT and DR values like done in cost calculations.

7. **Bifaciality** benefits are not shown.

AEG AS-M1443-H module
450 Wp peak power
25 year power warranty

SPR-MAX6-450-COM
450 Wp peak power
40 year power warranty

EPEAT
Observations

Fulfillment of Ecodesign goals:

Minimized Green-Washing Scope

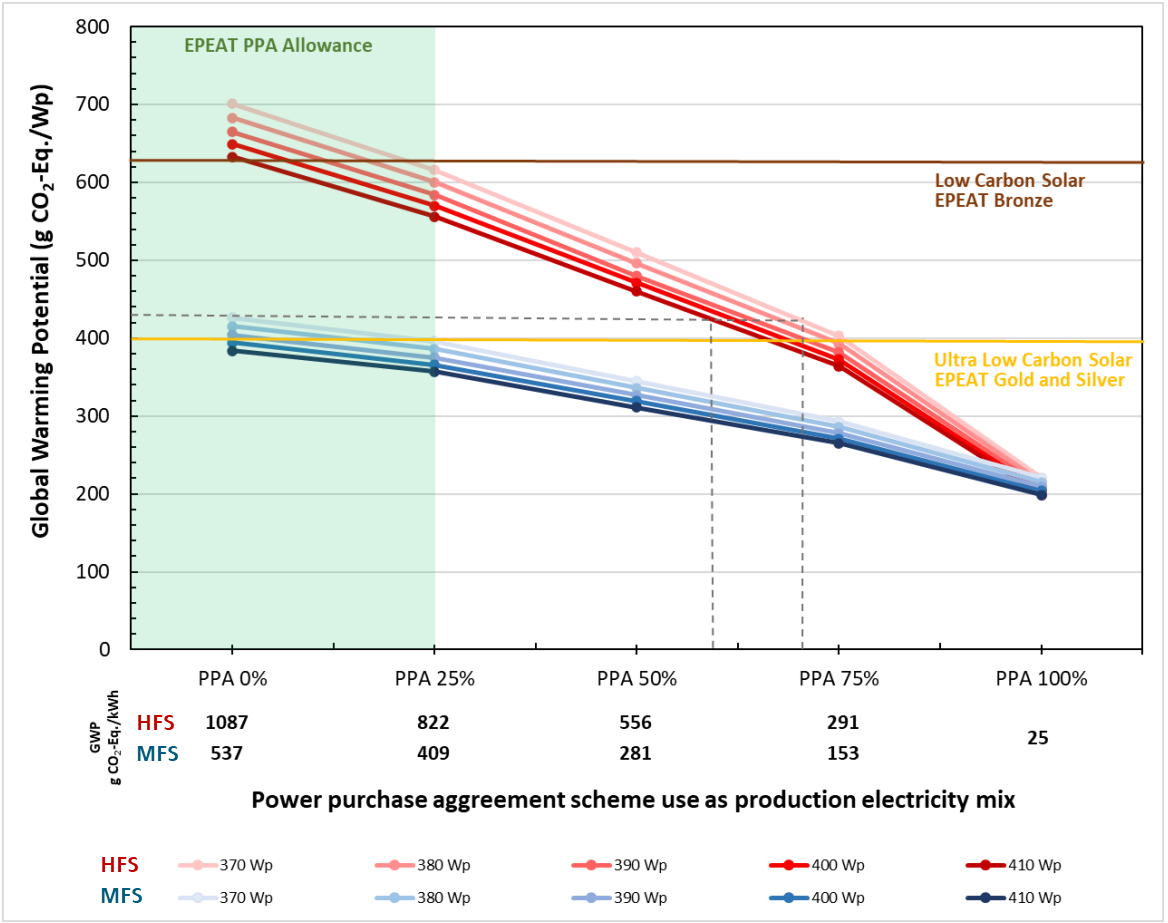
- Simplified calculation.
- Warranty (for LT, DR) avoidance, limited use PPA or equivalent certificates.

Comparable Labels

- Comparable impact when modules are characterized by peak power only.
- If the Ecodesign directive aims to portray the impacts throughout the lifetime then comparison may be incomplete as LT and DR is not considered.

Market Entry Regulation

- It is possible to regulate the market entry even if modules are only characterized by peak power as long as the minimum requirements for lifetime and degradation are set.



HFS: High Fossil Share; MFS: Moderate Fossil Share; PPA: Power Purchase Agreement

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Downstream: Sensitivity of Energy Yield (kWh)

To Lifetime, Degradation Rate and Module Power

PERC module energy yield			Lifetime (years)		
			15	30	40
20.11%, 370 W_p	**Degradation rate (%/a)**	1.50	6123	10693	12878
		0.70	6537	12349	15822
		0.25	6770	13280	17477
		0.00	6899	13798	18397
21.2%, 390 Wp		1.50	6454	11271	13574
		0.70	6890	13017	16677
		0.25	7136	13998	18422
		0.00	7272	14544	19392
22.28%, 410 Wp		1.50	6785	11849	14270
		0.70	7243	13684	17532
		0.25	7501	14716	19367
		0.00	7645	15290	20386

PEFCR (Ecodesign adaptation) climatic location requirement:
i. Subtropical arid, ii. Temperate continental and iii. Temperate coastal.

Only *Temperate Continental* is shown here.
In-plane solar irradiance 1266 kWh/m²a.

The overall **energy yield of a module can vary significantly** based on the following parameters.

- Lifetime 15 to 40 years: **+142% approx.**
- Degradation Rate 1.5% to 0%: **+29% approx.**
- Module Power 370Wp to 410Wp: **+11% approx.**

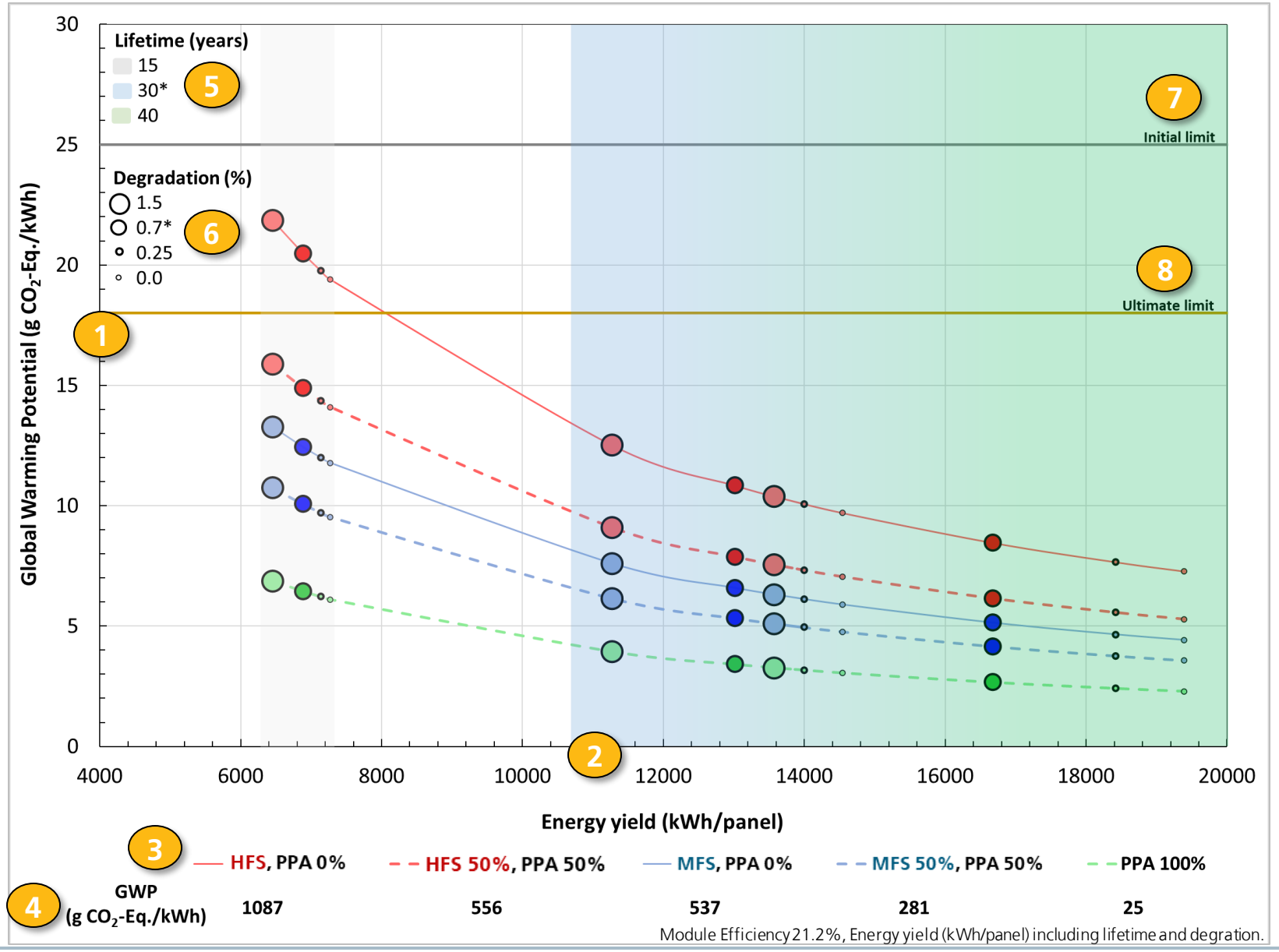
❖ Highly dependent on location driven factors like insolation, soiling/maintenance, probability of storm damage (e.g. hail), etc.

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

$$CSER = \frac{EY_{M(DC)Y1} \cdot G_{ref}}{P_{max,STC} \cdot H_p}$$

PEFCR
Diagram Orientation

1. Y-axis: GWP/kWh
2. X-axis: Energy yield (kWh/panel)
3. Module production electricity mix
4. GWP/kWh of production electricity mix
5. Lifetime: assumed *30 Y shall be used for PEFCR and Ecodesign [1]
6. DR: *0.7% recommended in PEFCR, 1% should be used for Ecodesign [1]
7. Initial market entry requirement 25 g CO_2-Eq./kWh
8. Ultimate market entry requirement 18 g CO_2-Eq./kWh



1. Ecodesign requirements for photovoltaic modules and photovoltaic inverters, Working document, version 2. This methodology is under development; values may be different in the latest version.

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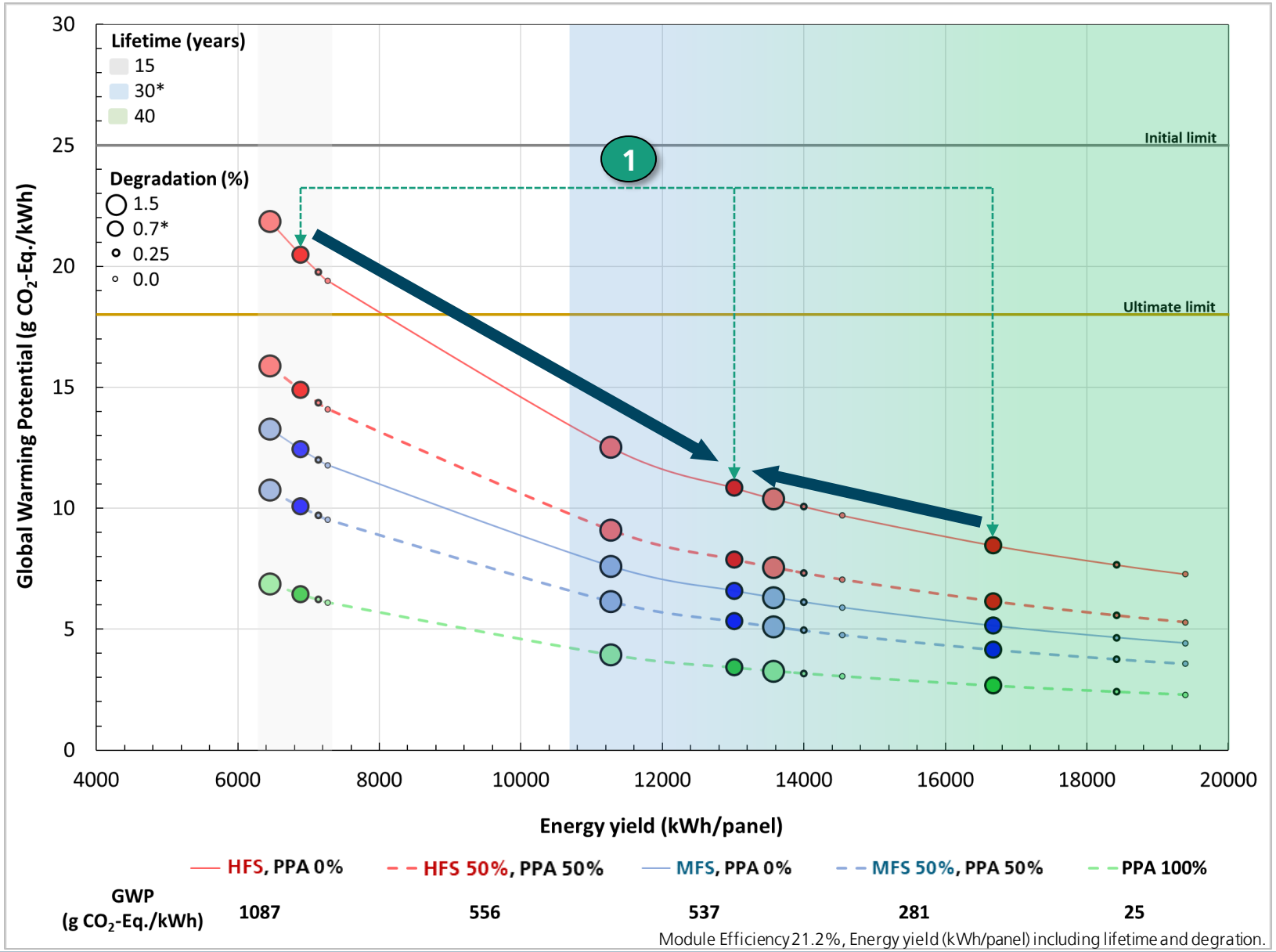
PEFCR

Ecodesign adaptation

Observations:

1. Shows the impacts over the complete lifetime as **30 years** [1] shall be used for assessment.
   - ➢ Equalizing lifetime for all modules; <u>difference in module performance quality not reflected</u>.
   - ➢ Should power warranty be used instead?
   - ➢ Greenwashing scope for modules with power warranty less than 30 years.
   - ❖ Ecodesign aims to set market entry barrier. Premium performance can be presented through Ecolabel directive.



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PEFCR
Ecodesign adaptation

Observations:

2. Degradation of **1%/year** [1] should be used
   - ➢ Equalizing degradation for all modules; can be changed with justification.
   - ➢ GWP difference from 0% to exemplary 1% DR is one of the missing picture on EPEAT if the scope of the label includes the complete lifetime.

1. Ecodesign requirements for photovoltaic modules and photovoltaic inverters, Working document, version 2. This methodology is under development; values may be different in the latest version.

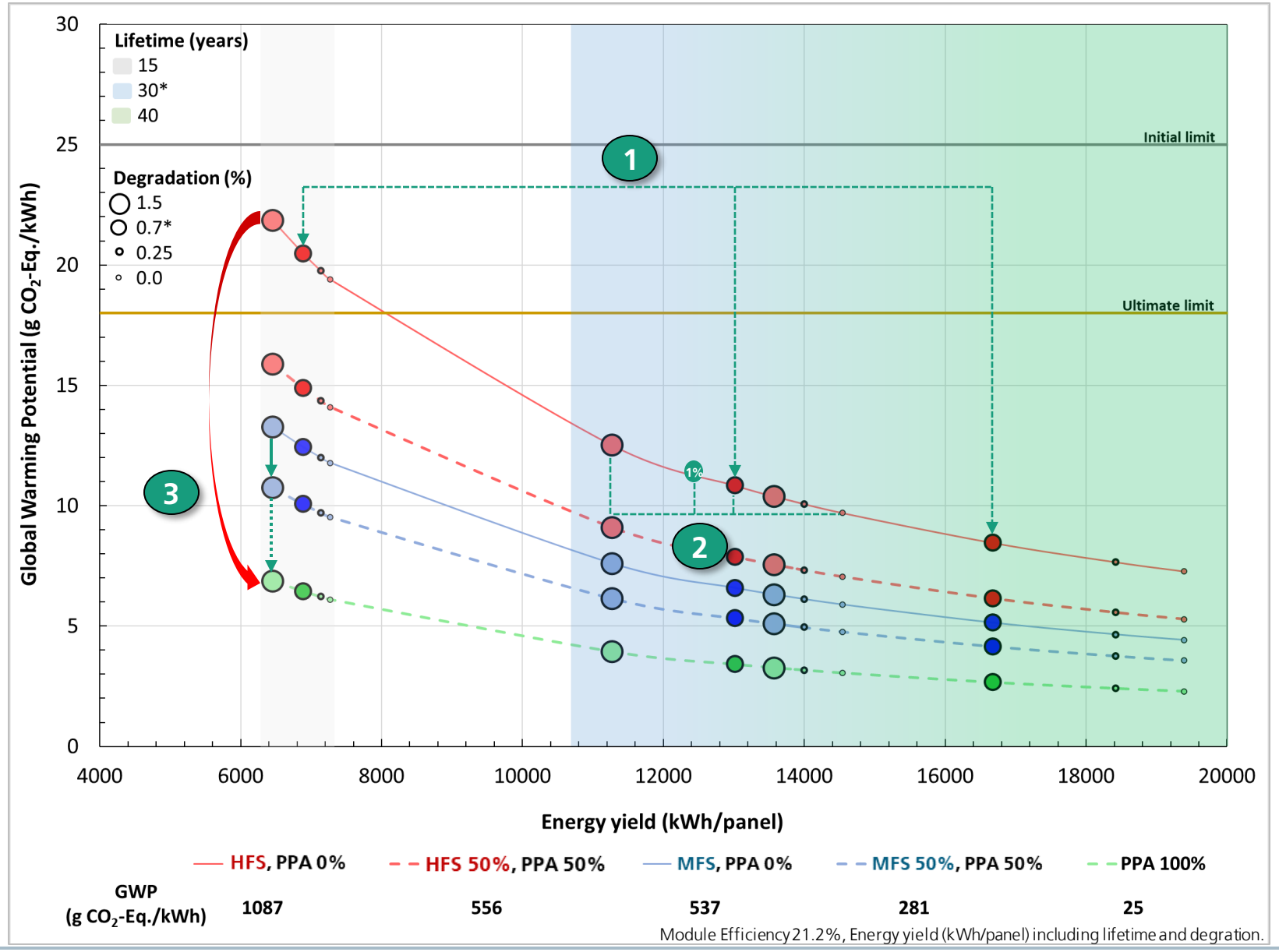
PEFCR

Ecodesign adaptation

Observations:

3. **Supplier-specific electricity prioritized:** Power purchase agreement (PPA) or equivalent certificates allowance 100% when the set of minimum criteria to ensure the contractual instruments are reliable is met.

   - ➢ Manufacturers can improve ecological-profile of their production irrespective of their region.
   - ➢ Creates motivation for national grid to improve.
   - ➢ EU manufacturers are vulnerable if global certifications can not be trusted.
   - ❖ Serious concern is observed throughout the European photovoltaic industry regarding the **credibility of global certificates** such as the PPA (or equivalent) and those certifying the raw material purchase.



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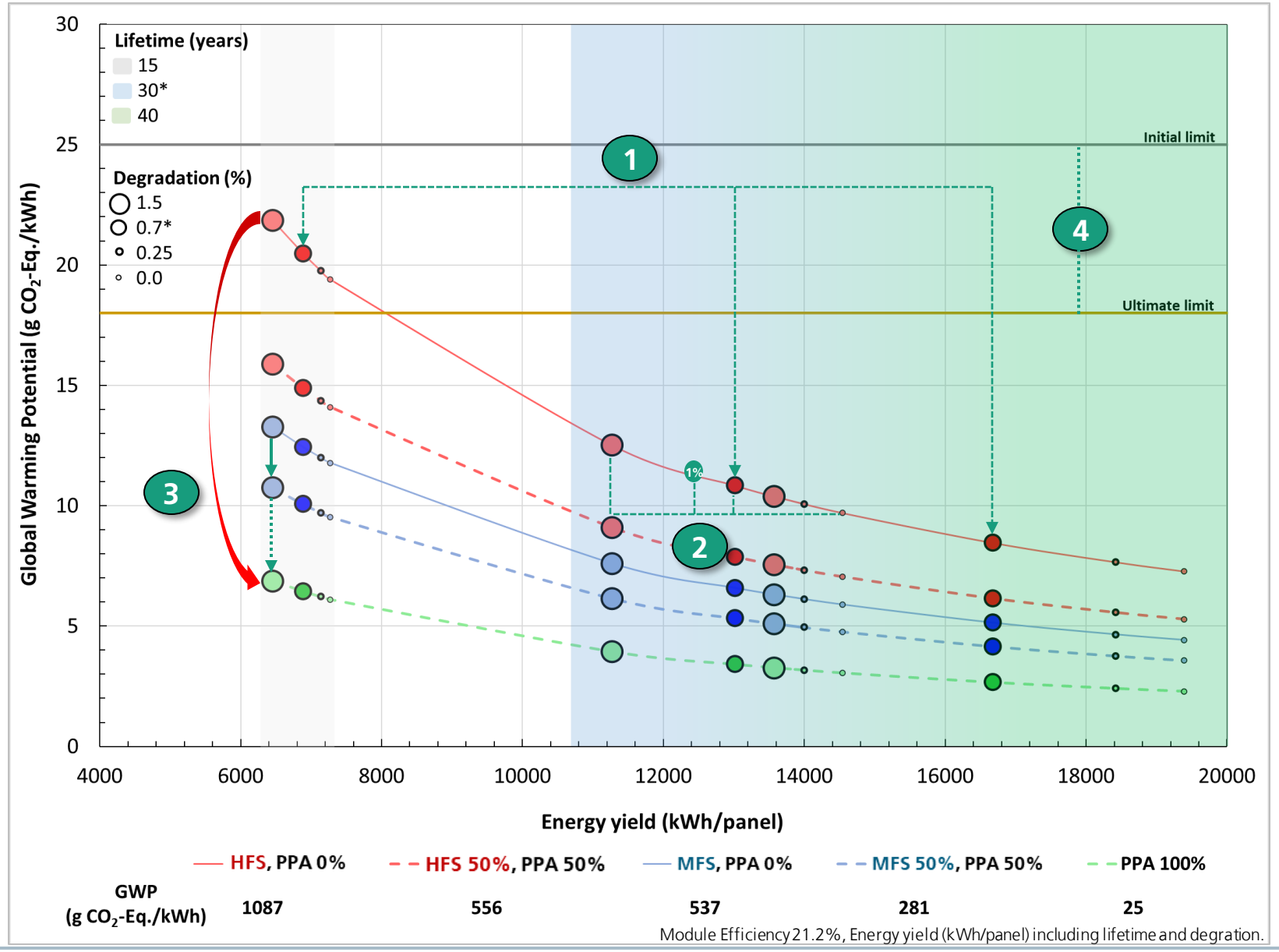
PEFCR

Ecodesign adaptation

4. The requirements **25 g CO_2-Eq./kWh** and **18 g CO_2-Eq./kWh** are relaxed for a module.[1]

   Which modules will be excluded from the market?

5. Includes provision for **bifaciality.**



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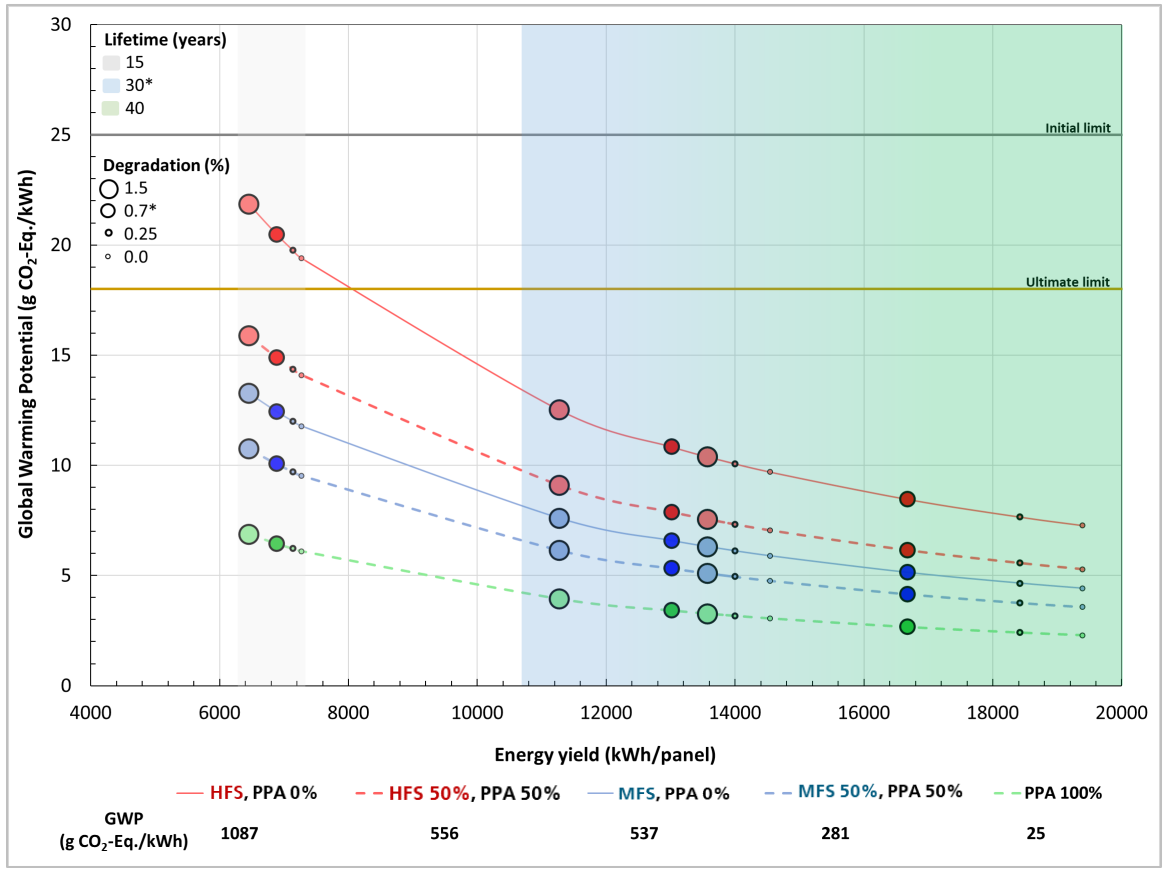
PEFCR

Ecodesign adaptation

Fulfillment of Ecodesign goals:

- **Minimized Green-Washing Scope**
  - Can global certificates (PPA, material purchase, etc) be reliably verified and tracked?
- **Comparable Labels**
  - If certificates are credible, comparable impact of modules on kWh.
  - Comparison may be inaccurate as overall performance of the module (LT and DR) is considered same for all, which could even lead to false impression.
- **Market Entry Regulation**
  - Will be decided by the success of the two points above.
  - If LT and DR are fixed, EPEAT methodology will be preferable for the EU manufacturers due to the 25% PPA allowance limit.



Ecological Regulation Methodology

Fulfillment of Ecodesign Directive Goals

Electronic Product Environmental Assessment Tool (EPEAT)

Minimized Green-Washing Scope

- Simplified calculation.
- Warranty (for LT, DR) avoidance in calculation, limited use PPA or equivalent certificates.

Comparable Labels

- Comparable impact of modules characterized by peak power only.
- If LT impacts are desired by Ecodesign directive → comparison may be incomplete as LT and DR is not considered.

Market Entry Regulation

- Possible to regulate the market entry as long as the minimum requirements for lifetime and degradation are set.

Product Environmental Footprint Category Rules (PEFCR) (Ecodesign adaptation)

Minimized Green-Washing Scope

- Can global certificates (PPA, material purchase, etc.) be reliably verified and tracked?
  - Serious concern is observed throughout the European photovoltaic industry.

Comparable Labels

- If certificates are credible, comparable impact of modules on kWh.
- Comparison may be inaccurate as LT and DR are considered same for all, which could even lead to false impression.

Market Entry Regulation

- Will be decided by the success of the two points above.
- If LT and DR are fixed, EPEAT methodology will be preferable for the EU manufacturers due to the 25% PPA allowance limit.

Conclusion

Both methodologies show advantages and disadvantages.

Minimized Green-Washing Scope:

- **EPEAT: Limited green washing opportunity** as 75% of electricity is national grid. Minimum requirements set for lifetime and degradation based on industry standards, updated every 3 years.
- **Adapted PEFCR:** More detailed calculation showing the carbon footprint of electricity produced by the module through out its lifetime.
  The lifetime and degradation shall be 30* years and 1%* for all modules and supplier-specific electricity (with certificate) will be prioritized.
  If certificates are not credible, **EPEAT may be preferable by the EU manufacturers as it offers the protection of the 25% PPA allowance limit**.

Comparable Labels:

- **EPEAT: Comparable labels**. If the Ecodesign directive aims to portray the impacts throughout the lifetime then comparison **may be incomplete** as overall performance of the module (lifetime and degradation) is not within scope.
- **Adapted PEFCR:** Label comparison **may be inaccurate** as overall performance of the module (lifetime and degradation) is considered same for all modules.

Market Entry Regulation:

- **EPEAT: Market entry regulation possible**. Leads to significant CO_2-gap between HFS and MFS due to **25% PPA limit → No buy-out opportunity** .
- **Adapted PEFCR:** The **success of the Ecodesign directive will depend highly on the credibility of the certificates** and its verification processes for flexible parameters like PPA use **→ buy-out opportunity.**
  The market entry requirements set by Ecodesign currently (25 and 18 g CO_2-Eq./kWh) are very relaxed **→ almost no exclusion.**

*Ecodesign requirements for photovoltaic modules and photovoltaic inverters, Working document, version 2. This methodology is under development; values may be different in the latest version.

Thank you!

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