



2-3 December 2025 Málaga, Spain

Sustainability Policies : A New Era for PV Modules

Nouha GAZBOUR, Phd

Head of the Sustainability Team

Nouha.gazbour@cea.fr



CEA at INES, Le Bourget du Lac, France



OPCon
SHJ
Candem

Increase performance

Reduce cost, consumption and environmental impact

Characterization, modelization

Increase Stability, fiability, durability



SUMMARY

1. Sustainability standards in the PV sector

- *What are the latest European and French environmental regulations ?*

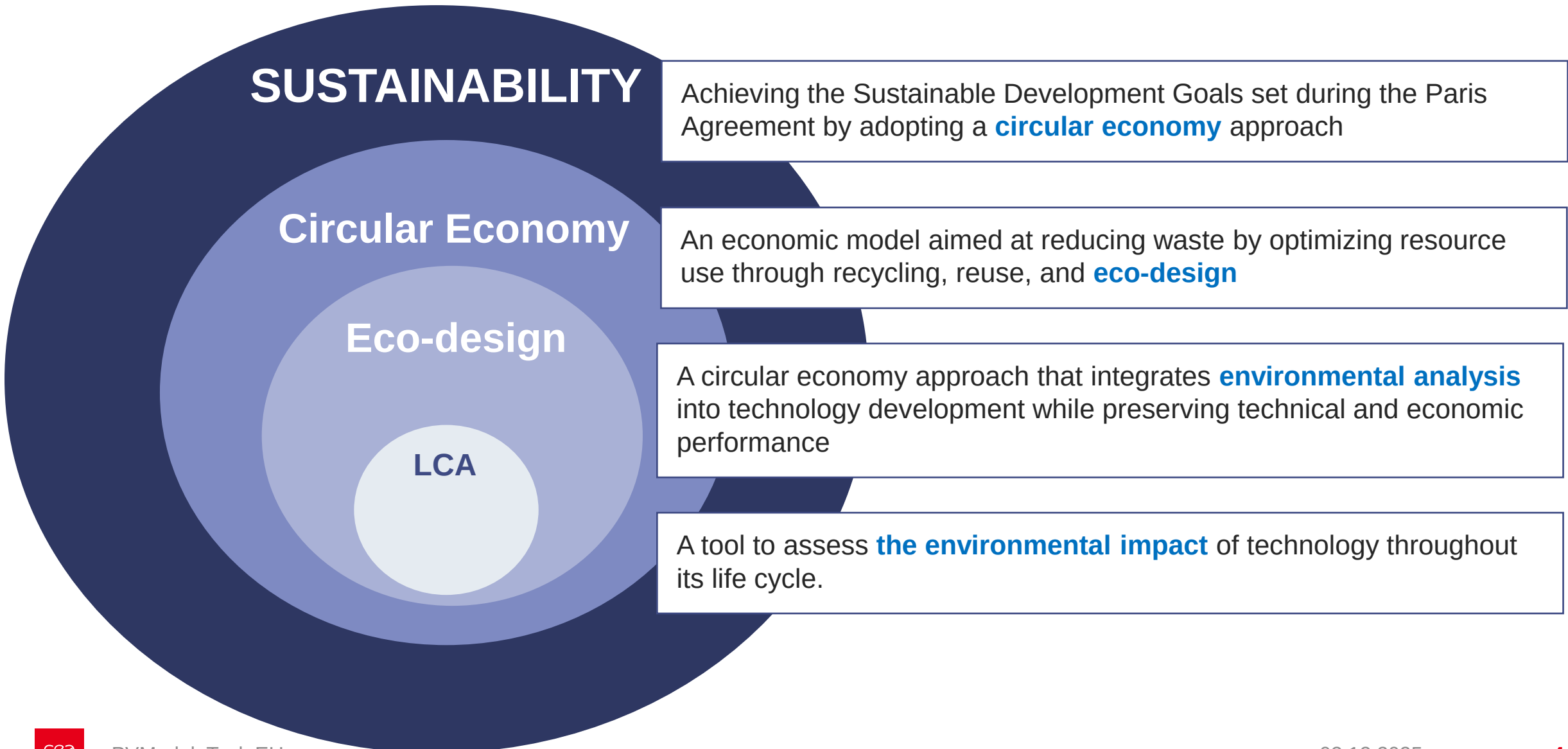
2. Innovation X Regulations

- *How can these regulations drive innovation in PV module design and manufacturing?*
- *Which risks and opportunities do they create for the PV sector ?*

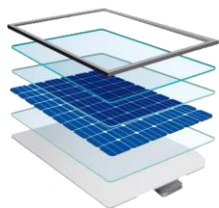
3. Variability and impact

- *How do these regulations differ between them ?*
- *What is the impact of these differences on compliance and results ?*

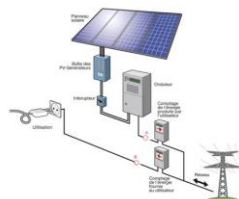
Sustainability : Concepts and Approaches



SUSTAINABILITY STANDARDS IN THE PV SECTOR



Manufacturing



Installation & Use



End of life

- « Critical raw material act »
- « European Forced Labour regulation »
- « Environmental Product Declaration »
- « Simplified carbon footprint evaluation »
- Eco-modulation criteria
- Ecolabel EPEAT
- « Net Zero Industry Act (NZIA) »
- Recyclability Index
- VAT 5,5%

- EU Eco-design Energy Labelling
- EU Eco-design Energy Labelling
- EU Ecolabel
- Green Public Procurement
- Taxonomie EU

- Directives WEEE
- Landfill taxing



EUROPEAN POLICIES : NZIA



A key objective of the NZIA is to produce at least 40% of the world's manufacturing capacity for low-carbon technologies within the EU by 2030.

Each Member State must include **non-price criteria in tenders**, notably **resilience**, **carbon footprint** and **Recyclability**

- ❑ **Resilience (Current definition)** : A PV module is considered **resilient** if four components in the value chain are **not produced** in a third country accounting for more **than 50% of European imports**,:
 - **3 mandatory components**: Cell **+** Module **+** inverter
 - **1 additional component of choice**: polysilicon **OR** ingot **OR** wafer **OR** glass **OR** tracker
- ❑ **Carbon Footprint** : According to the latest published Article 8, each Member State may choose its own calculation method until the EU implements the **PEFCR method** .
- ❑ **Recyclability index** : This is a recyclability **scoring indicator** (Recyclability Index) applicable to PV modules and PV inverters and depending on the module composition



FRENCH POLICIES



REGULATIONS	SEGMENT	CRITERIA	THRESHOLD
« Simplified Carbon Footprint Evaluation »	Call of tender for PV on Building > 500 MW	Carbon footprint	< 740 kgCO ₂ eq/KWp
	Call of tender for PV on Utility scale	Carbon footprint	< 550 kgCO ₂ eq/KWp
VAT 5.5%	Call of tender for PV on Residential < = 9 KWp	- Carbon Footprint - Quantity of silver - Lead content - Cadmium content	< 530 kgCO ₂ eq/KWp < 14 mg/Wp < 0.1% < 0.01%
Eco-modulation criteria	All segment and each market operator	- Carbon Footprint - Quantity of silver - Recycling rate - Lead content	< 450 and < 630 kgCO ₂ eq/KWp < 14 mg/Wp > 3% < 0.1%

+ Resilience criteria from 2026

SUMMARY

1. Sustainability standards in the PV sector

- *What are the latest European and French environmental regulations ?*

2. Innovation X Regulations

- *How can these regulations drive innovation in PV module design and manufacturing?*
- *Which risks and opportunities do they create for the PV sector ?*

3. Variability and impact

- *How do these regulations differ between them ?*
- *What is the impact of these differences on compliance and results ?*

SUPPLY CHAIN OUTSIDE CHINA : Q1 2025



Production capacity	Polysilicon	Ingot	Wafer	Cell	Module
South East Asia	82,000 tons	-	16 GW	51.3 GW	86 GW
India	-	2 GW	14 GW	24.56 GW	68.441 GW
Europe	60,000 tons	-	-	3.2 GW	21 GW
South Africa	-	-	-	2.5 GW	3.3 GW
US	171,000 tons	-	-	8 GW	31.92 GW

Source : <https://sinovoltaics.com/sinovoltaics-supply-chain-maps/>



Module Resilience could be attainable but What about Carbon Footprint threshold ?

COMPLIANCE RESILIENCE + CARBON FOOTPRINT

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Polysilicon	China	Malaisia	China	Germany	Germany	Germany	US
Ingots	China	China	China	China	China	China	China
Wafer	China	China	China	China	China	China	China
Cell	Vietnam	Vietnam	India	Turkey	Italy	France	US
Module	Vietnam	Vietnam	India	Turkey	Italy	France	US
Glass	India	China	India	China	China	China	China
Inverter	SEA	SEA	SEA	SEA	SEA	SEA	SEA

Resilience (current definition)

✓

✓

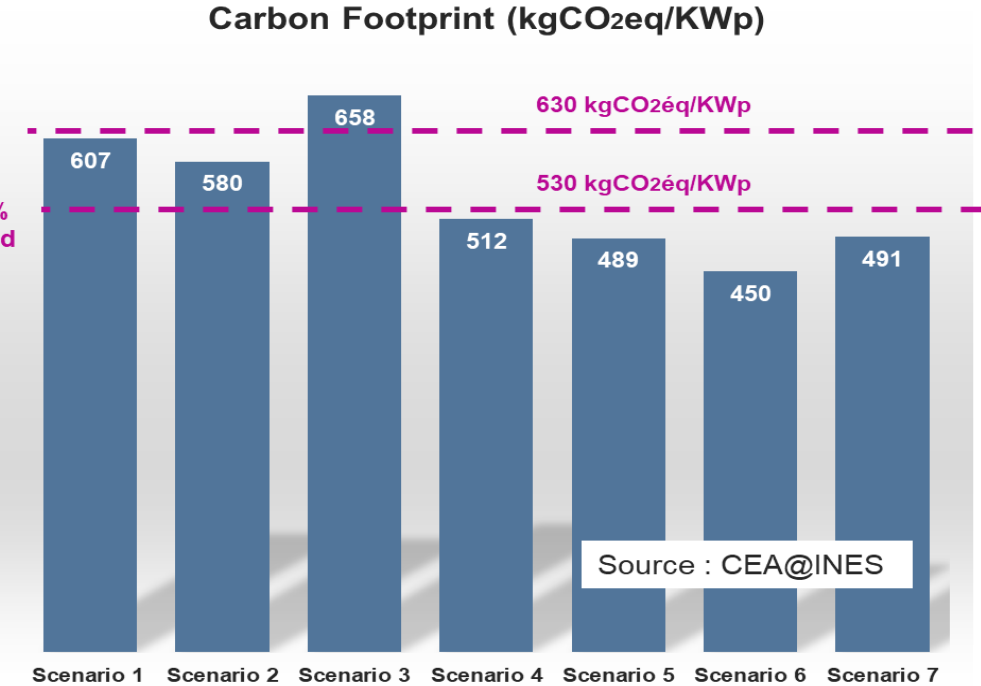
✓

✓

✓

✓

✓



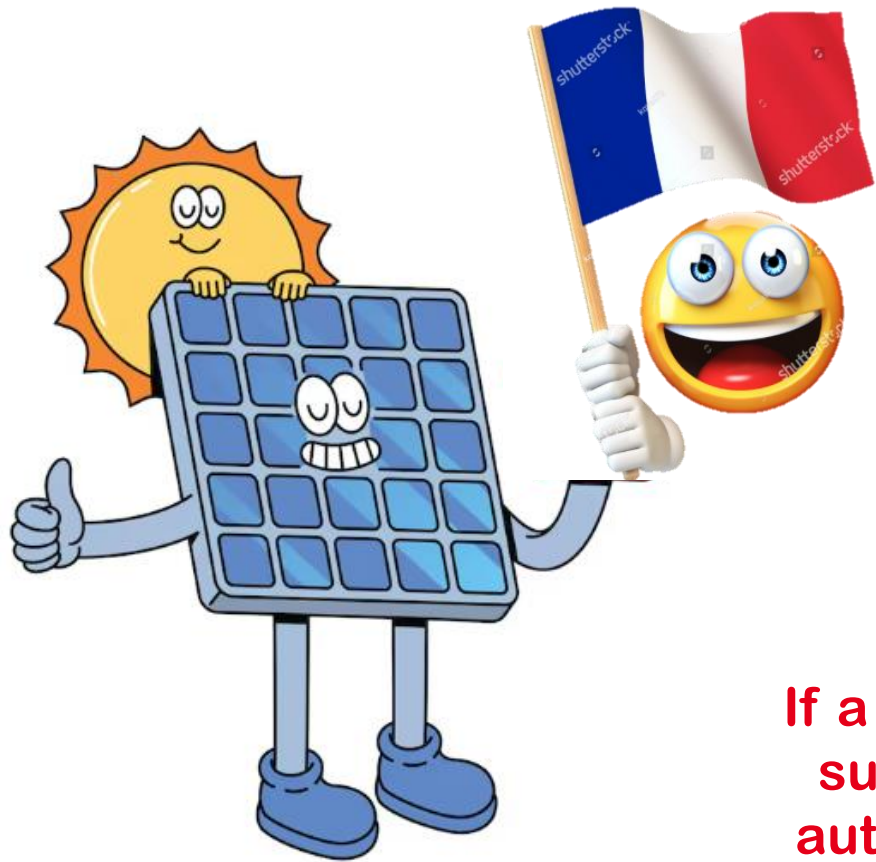
Method : French methodology, PPE2 V2
Module performance :
Glass/Glass module,
Power : 615 Wp,
Wafer Thickness : 130 um

Link : <https://www.certisolis.com/certisolis/bilan-carbone/>



PS : These results could vary with the variation of the performance of the module

Significant impact of the production location on the carbon footprint



If a PV module is certified as sustainable in France, is it automatically eligible under regulations in other countries ?



SUMMARY

1. Sustainability standards in the PV sector

- *What are the latest European and French environmental regulations ?*

2. Innovation X Regulations

- *How can these regulations drive innovation in PV module design and manufacturing?*
- *Which risks and opportunities do they create for the PV sector ?*

3. Variability and impact

- *How do these regulations differ between them ?*
- *What is the impact of these differences on compliance and results ?*



CARBON FOOTPRINT REGULATIONS

MAINLY FOCUS ON THE CARBON FOOTPRINT



Since 2007

- **ECS - Call of tender:** $< 550 \text{ kgCO}_2\text{eq/KWp}$ (Mandatory)
- **ECS – Call of tender Building :** $< 740 \text{ kgCO}_2\text{eq/KWp}$ (Mandatory)
- **5.5% VAT :** $< 530 \text{ kgCO}_2\text{eq/KWp}$ (Mandatory)



Since 2023

- **EPEAT - Low Carbon Solar panels (LCI):** $< 630 \text{ kgCO}_2\text{eq/KWp}$ (Mandatory)
- **EPEAT - Ultra Low Carbon Panels (ULCI):** $< 400 \text{ kgCO}_2\text{eq/KWp}$



Since 2015

- **Eco-design label_PFECR (Mandatory):** Threshold ? $\text{kgCO}_2\text{eq/KWh}$
- **Green Pact (Carbon Taxonomy)**



Since 2020

- **Only call of tenders - Three grades**
I: $\leq 670 \text{ kgCO}_2\text{eq/KWp}$
II: $671 - 830 \text{ kgCO}_2\text{eq/KWp}$
III: $> 830 \text{ kgCO}_2\text{eq/KWp}$



Why various thresholds on carbon footprint ?



VARIABILITY OF THE REGULATIONS



All initiatives are based primarily on the **Life Cycle Assessment (LCA) method**

1 Perimeter of the study

2 Method of the analysis

3 Data base



Laminated module
Without frame and transport

IPCC 2021,GWP, 100 ans
Intergovernmental Panel on Climate Change,
Global Warming Potential

Ecoinvent 3.9



Production + Use + Distribution
+ End of Life

EN 15804 + A2 method
Environmental norm for construction

Ecoinvent
not specified



Laminated module + Frame +
Transport

IPCC 2013, GWP, 100 ans

Ecoinvent 3.8



Production + Installation + Use
+ Distribution + End of Life

EF method
Environmental Footprint

Ecoinvent
not specified

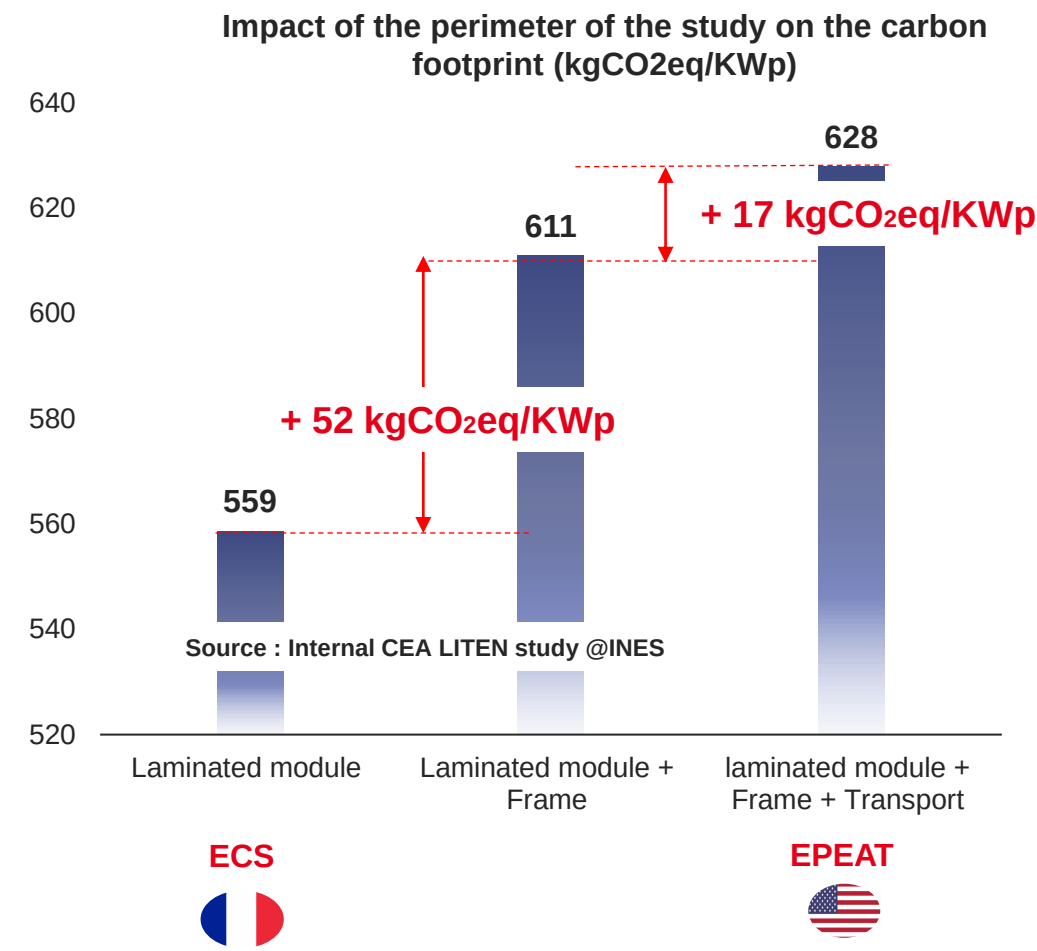
Variation in terms of **the perimeter of the study, method and data bases**



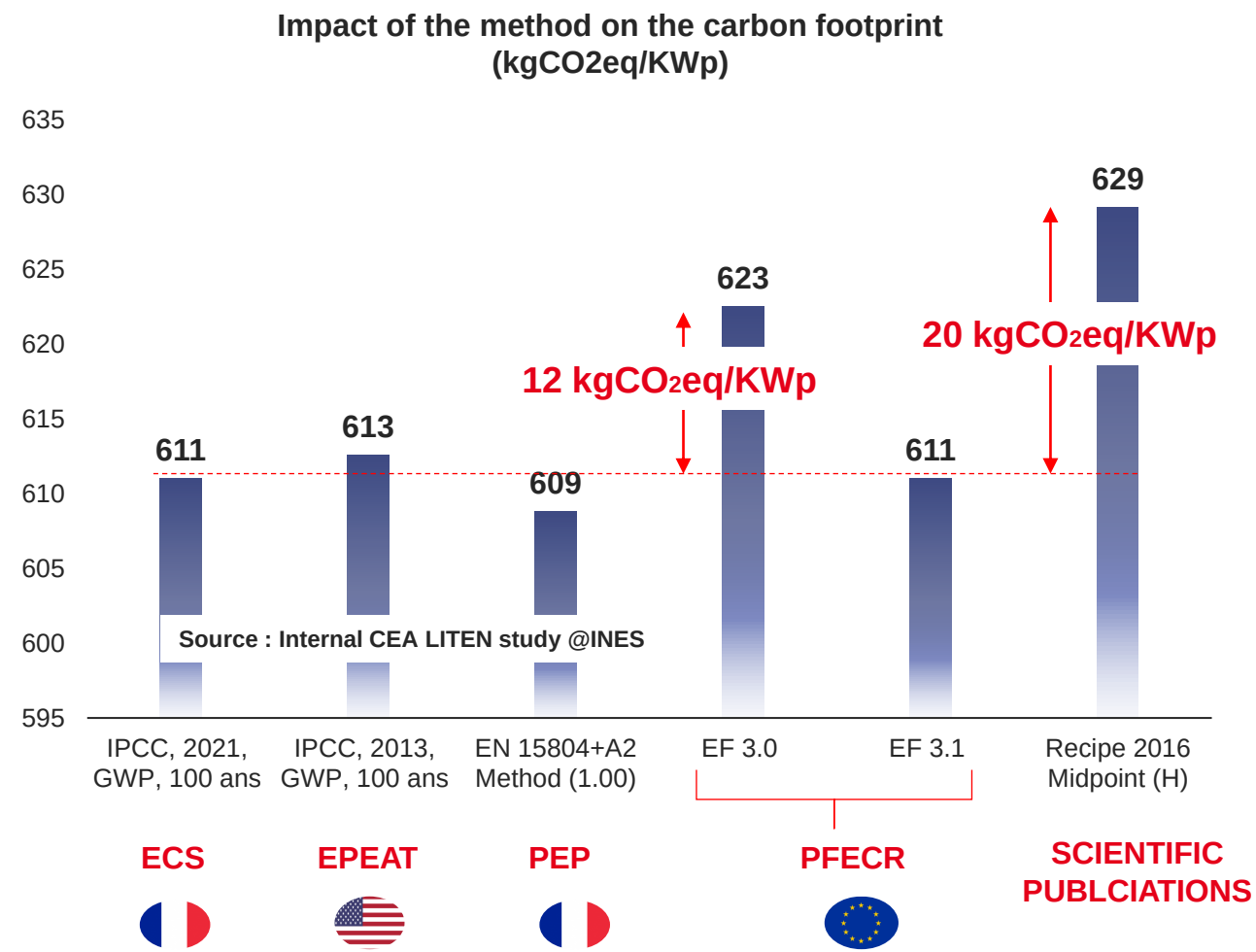
**What is the impact on the
environnemental results ?**

IMPACT OF THE VARIABILITY

1 Perimeter of the study

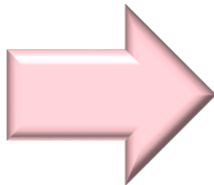
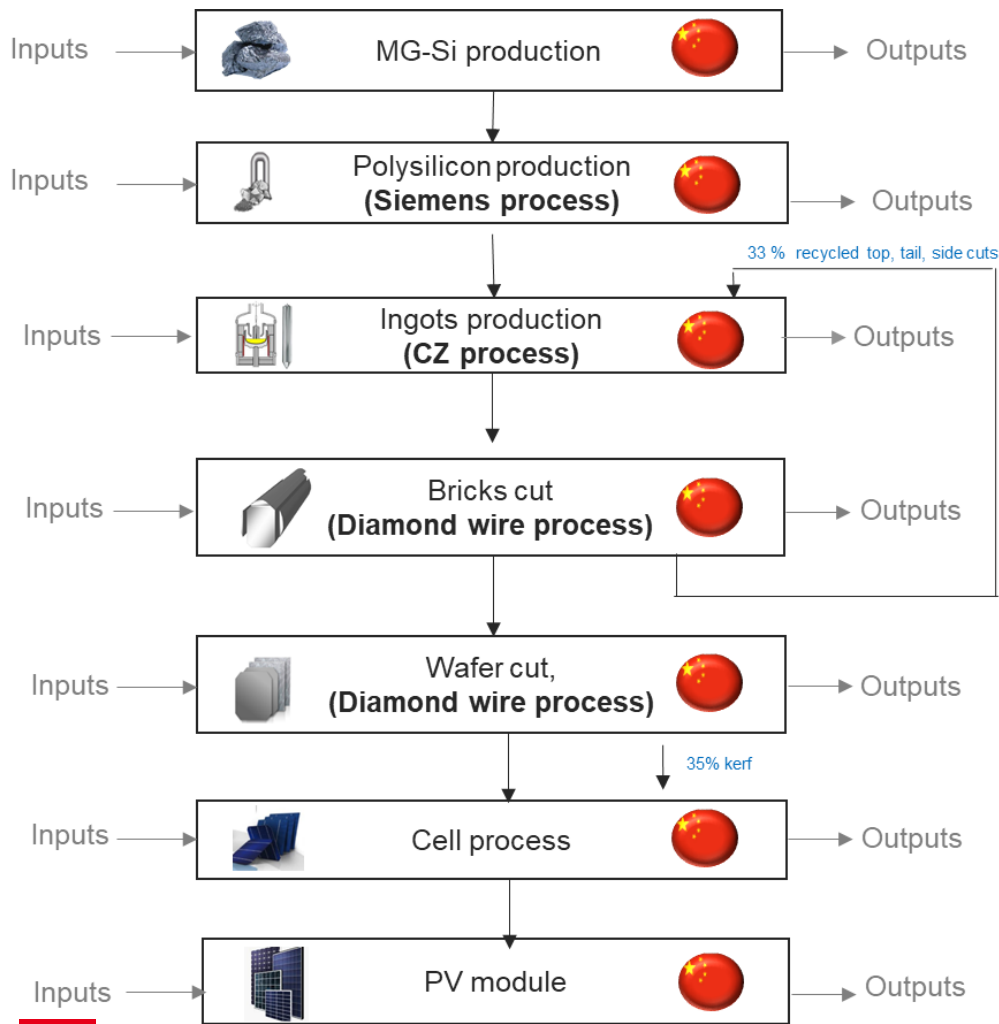


2 Method of the analysis

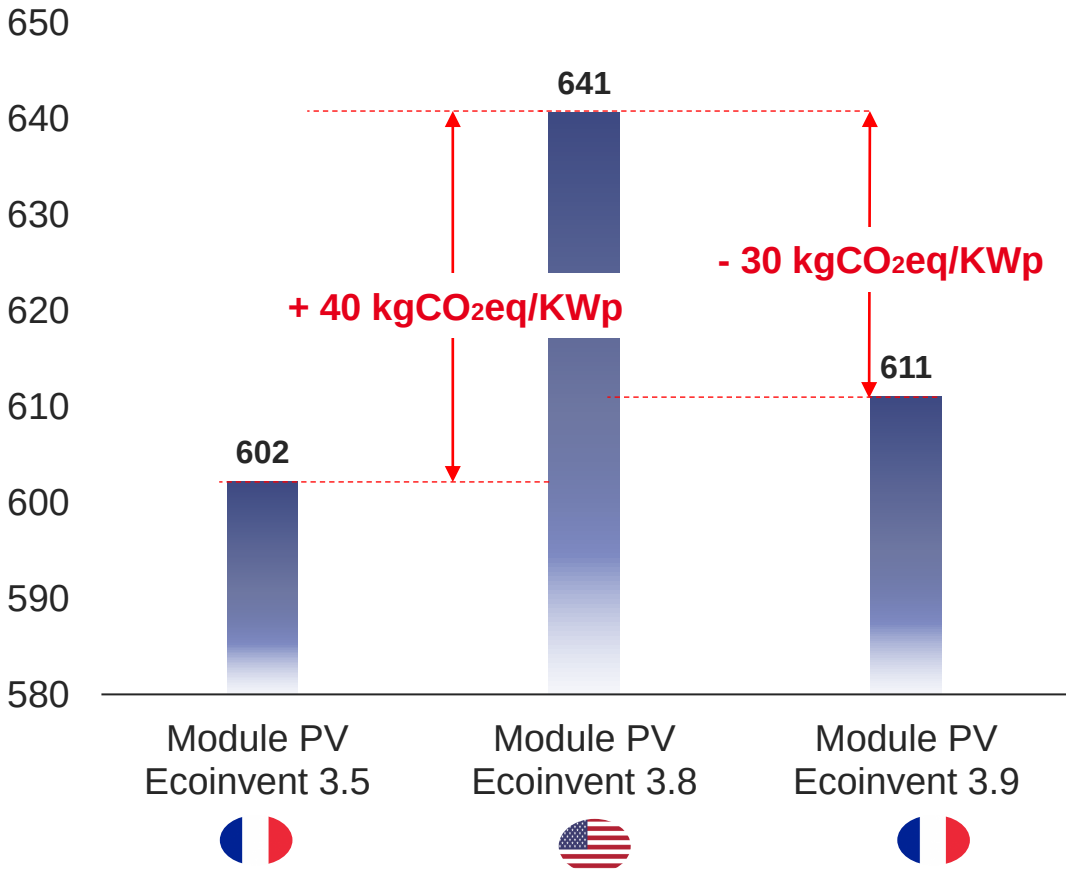


IMPACT OF THE VARIABILITY

3 Data base



Impact of the data base on the carbon footprint (kgCO₂eq/KWp)



Source : Internal CEA LITEN study @INES

The same PV module can pass the regulations by varying the data base

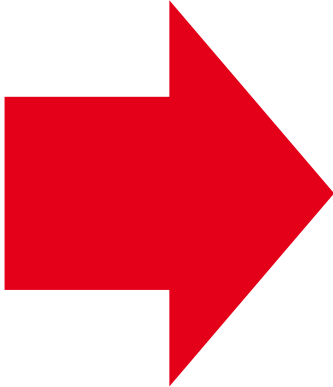


VARIABILITY OF THE REGULATIONS

Variability on the **perimeter** of the study

Variability on the **method** of analysis

Variability on the **data base**

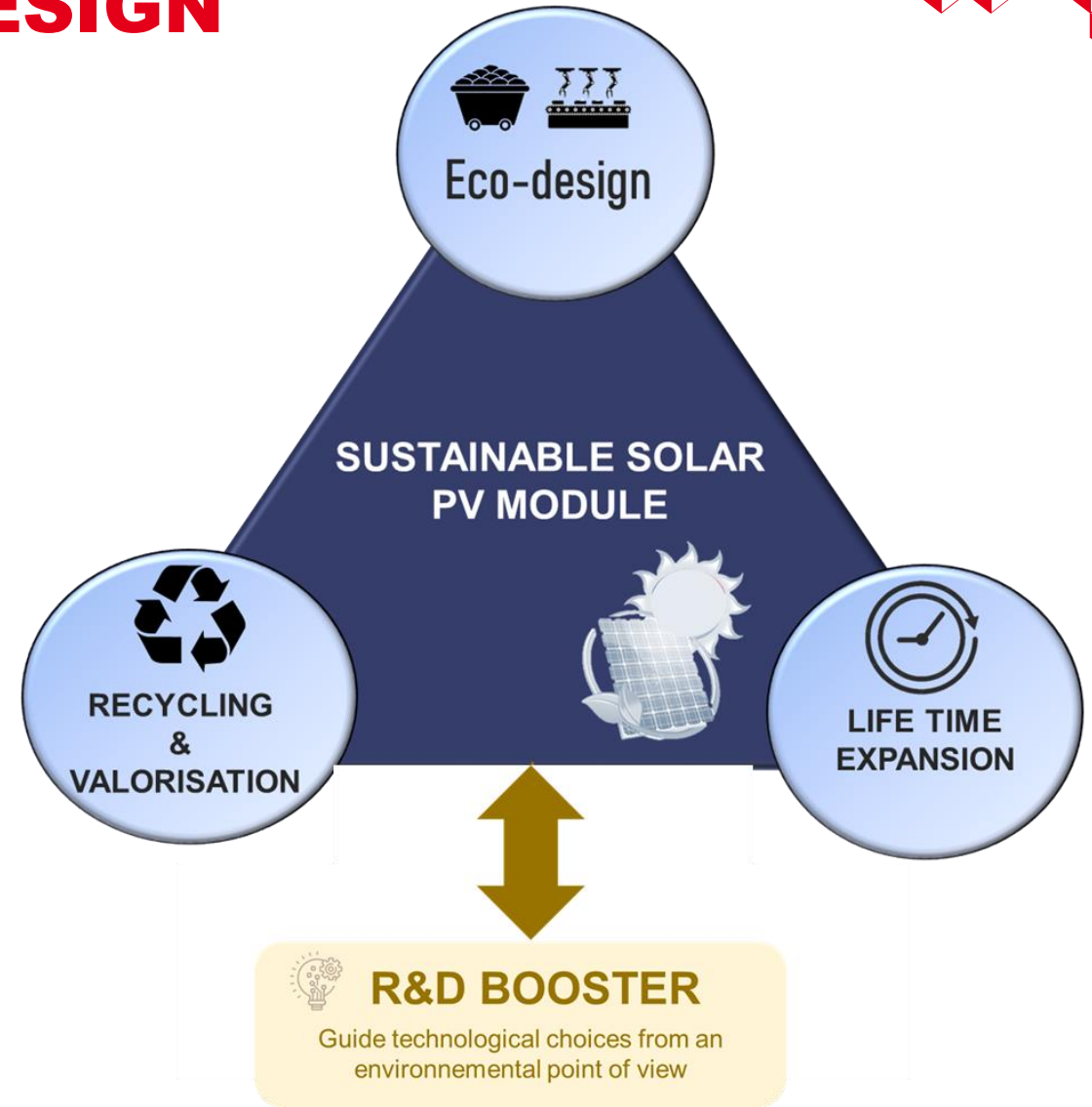
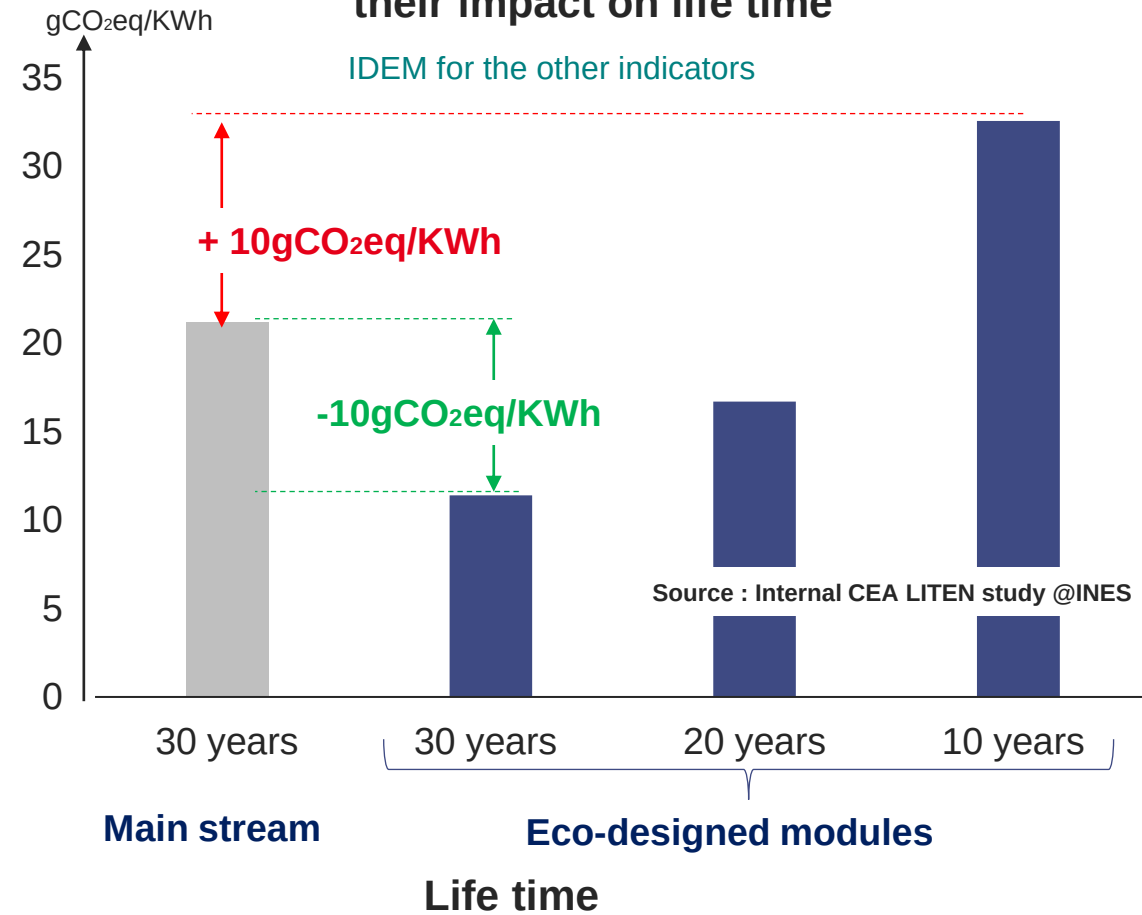


**VARIOUS
THRESHOLD OF
THE CARBON
FOOTPRINT
SEVERAL
CERTIFICATION
FOR THE SAME
MODULE**

**REGULATIONS AT THE MANUFACTURING
STAGE YES BUT**

A SUSTAINABLE PV MODULE DESIGN

Impact of the Eco-design alternatives on the carbon footprint taking into account their impact on life time



Need for a **global multicriteria approach** from **R&D level** to ensure the sustainability from the **early design process**

Research & Education
for **Solar Energy**

Follow us : ines-solaire.org

Nos champs d'applications



Photovoltaïque haut rendement

Le solaire photovoltaïque haut rendement à forte compétitivité



Photovoltaïque intégré X-IPV

Le solaire intégré pour toutes applications



Photovoltaïque et stockage au service du mix énergétique

Solutions pour l'intégration massive du photovoltaïque



Du bâtiment à la smart-city

Le bâtiment, cœur énergétique au cœur de la smart-city



Les Smart-grids multi énergies

Les réseaux intelligents au service des territoires



Économie et environnement

Vers une maîtrise de l'impact environnemental des dispositifs photovoltaïques

THANK YOU