



IEA PVPS Task 12: Advancing LCA & LCI for Photovoltaics: New Data, Studies, and Insights from IEA PVPS Task 12

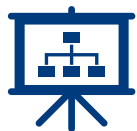
Nouha GAZBOUR, Michael Götz, Matthias Stucki.

Rotterdam, EUPVSEC, September 16, 2026

IEA PVPS Task 12: PV Sustainability



The aim of IEA PVPS Task 12 is to promote international cooperation and knowledge building in the field of environmental and social sustainability of PV.



Task 12 Subtasks

Subtask 1: Circular Economy (CE)

Subtask 2: Life Cycle Assessment (LCA)

Subtask 3: Ecosystem Integrated PV (ecoPV)

Subtask 4: Broader Sustainability Aspects (BSA)



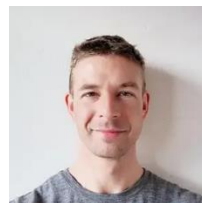
Task 12 Life Cycle Inventory Updates & Life Cycle Assessment



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Schweizerische Eidgenossenschaft
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Confederaziun svizra

Swiss Federal Office of Energy SFOE

IEA-PVPS Inventory Data and Report

Task 12 LCI Reports

- Published in 2011, 2015 and 2020. The **2026 version have been released this summer.**

Scope

- The report provides life cycle inventories for PV modules and balance-of-system components.

PV modules

- Updated inventories for commercial TOPCon, PERC and thin-film CdTe modules.

Balance of system

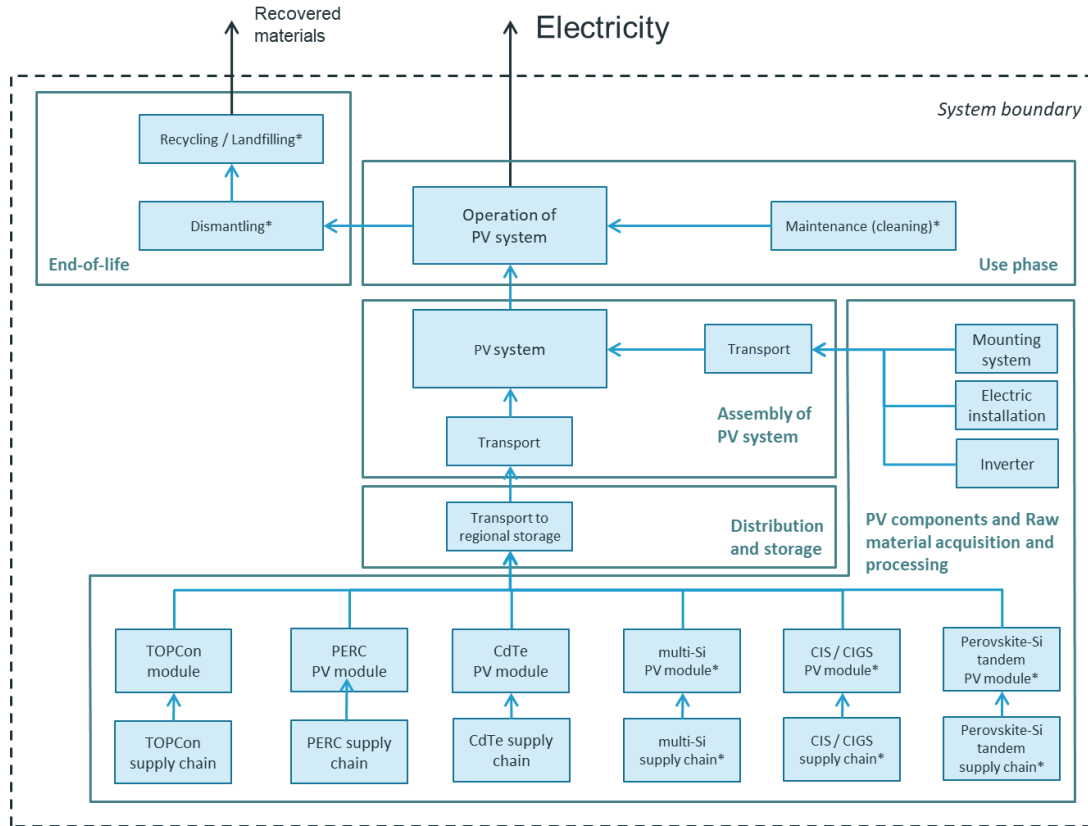
- LCI data cover residential, commercial and utility-scale PV systems including inverters, mounting structures, electric installation etc.

Quality assurance

- The updated inventories underwent a multi-step quality assurance process.



PV Product System



* Not updated from previous 2020 LCI release

The diagram represents Task 12's entire LCI framework, not the specific 2026 update.

The Data Challenge in PV Life Cycle Inventories



Data vintage



Widely used PV LCI datasets are often outdated and do not reflect current technology.

Rapid technology change



Cell architecture, wafer formats, energy and material efficiency evolve rapidly.

Data availability



Factory-level data along the PV supply chain are confidential and not publicly available.

Representativeness



Manufacturers are rarely willing to share externally verified data, so samples stay small and not market-representative.

Conventional data collection struggles to keep pace with a fast-moving and confidential supply chain.

An Innovative Approach to the Data Challenge



Conventional

Relies on manufacturers' willingness to share data, with high effort, low participation and limited representativeness.



New approach

France's PV tenders score every bid on a simplified carbon footprint (Évaluation Carbone Simplifiée, ECS), calculated across all supply-chain components.

To compete, manufacturers can provide detailed factory LCAs, which are then independently verified.

Verified factory LCAs are aggregated and fully anonymized, yielding IEA PVPS Task 12 LCI data as a by-product of an existing policy mechanism.

Additional Data Sources



- **CdTe thin-film module LCI data** (First Solar) 
- **Inverter LCI data** provided by manufacturers (fully anonymized)
- **Global market shares** at different supply chain stages (IEA PVPS Task 1, SPE)
- **Average module efficiencies** for TOPCon and PERC: ITRPV (2025)
- **Simulated PV module supply chain data** (Brailovsky, P., Fraunhofer ISE)  **Fraunhofer**
ISE
- **Background data:** open-source LCI database (FOEN/BAFU:2025)  Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra Federal Office for the Environment FOEN

Environnemental regulations in the PV sector



MAINLY FOCUS ON THE CARBON FOOTPRINT



Since 2013

- **ECS - Call of tender:** < 550 kgCO₂eq/KWp and < 740 kgCO₂eq/KWp
- **Tariff Order 2021** (Building installations > 100 KWp): < 550 kgCO₂eq/KWp
- **EPR criteria :** < 630 kgCO₂eq/KWp and < 450kgCO₂eq/KWp
- **VAT 5,5% :** < 530 kgCO₂eq/KWp



Since 2023

- **EPEAT - Low Carbon Solar panels (LCI):** < 630 kgCO₂eq/KWp
- **EPEAT - Ultra Low Carbon Panels (ULCI):** < 400 kgCO₂eq/KWp



Since 2020

- Only call of tenders - Three grades
- I: <= 670 kgCO₂eq/KWp
- II: 671 – 830 kgCO₂eq/KWp
- III: > 830 kgCO₂eq/KWp



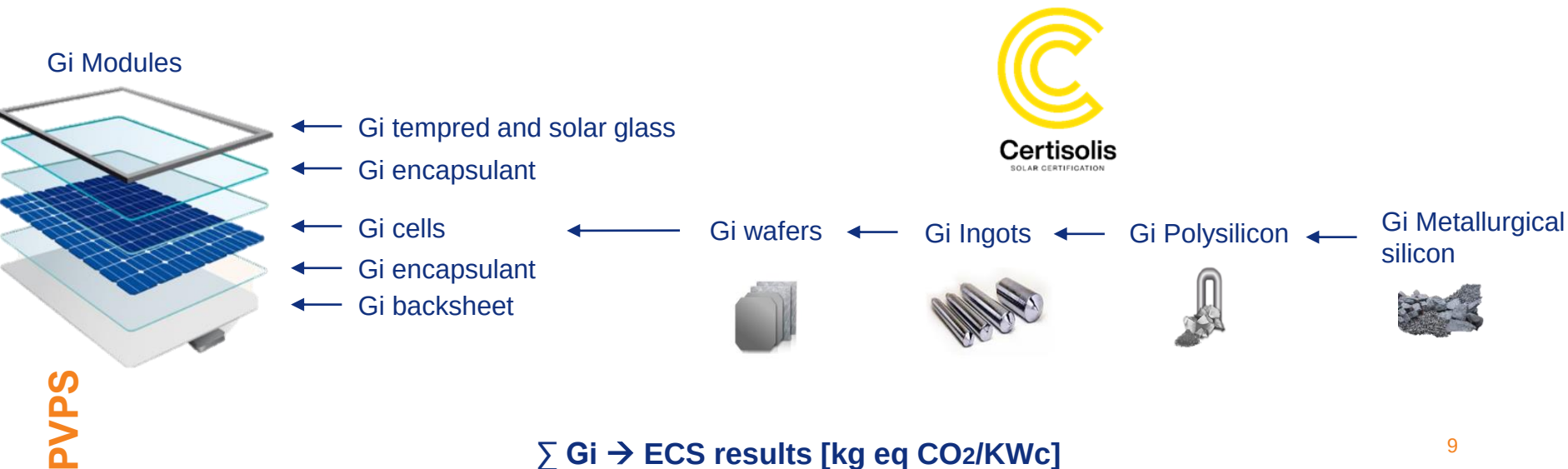
France: A Pioneer in Solar Carbon Footprint Regulation

Simplified Carbon Footprint (ECS) evaluation, what is it ?



• Calculation

1. Carbon Footprint G_i per component using **Default values based** or **LCA Values (validated by ADEME)**
2. Quantity of materials per component



Simplified Carbon Footprint (ECS) evaluation, what is it ?

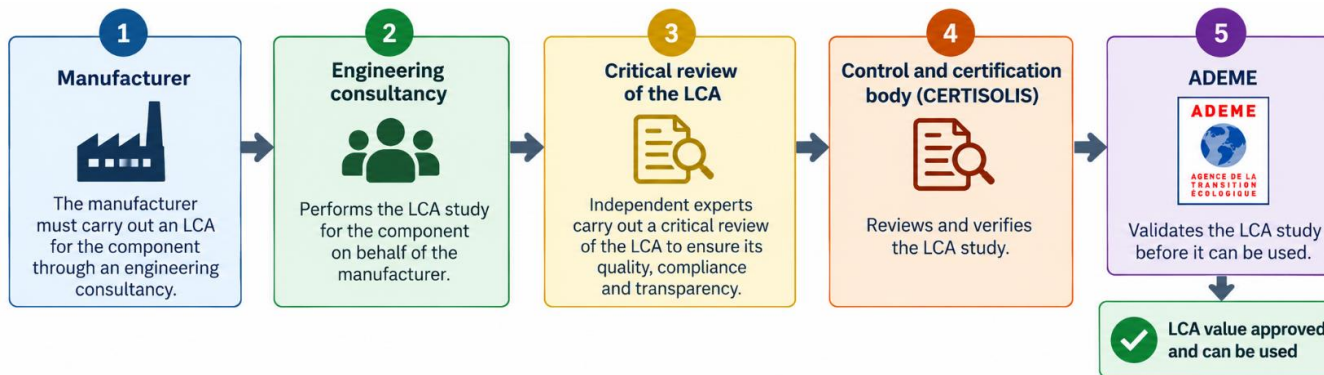


1. Carbon Footprint Gi per component

- **Default value** : GHG emission value (in CO₂eq) per component unit for the manufacturing of each component.
- **LCA value** :

Tableau 3 : Valeurs des émissions de GES en CO₂eq pour la fabrication des composants :
GWP = Global Warming Potential , Méthode : IPCC2021 GWP100 ans, Logiciel : Sima Pro 3.9
Base des données : Ecoinvent 3.9, Sources: CEA INES

Etape de fabrication / Matériau	Unité	Autriche	Belgique	Bulgarie	Suisse	Chypre	République Tchèque
Silicium Métallurgique MG-Si	kg CO ₂ -eq/kg	7,73	7,11	10,74	5,22	16,89	12,25
polySi, Siemens process	kg CO ₂ -eq/kg	29,72	25,81	48,88	13,78	88,02	58,51
Réalisation du Lingot, mono	kg CO ₂ -eq/kg	16,52	14,74	25,28	9,24	43,17	29,68
Réalisation du lingot, multi	kg CO ₂ -eq/kg	2,44	2,05	4,36	0,85	8,27	5,32
Réalisation du lingot, monolike	kg CO ₂ -eq/kg	5,07	4,68	6,99	3,48	10,90	7,95
Réalisation de la brique	kg CO ₂ -eq/kg	0,87	0,80	1,20	0,59	1,87	1,36
Fabrication des plaquettes mono	kg CO ₂ -eq/m ²	3,72	3,44	5,08	2,59	7,86	5,76
Fabrication des plaquettes multi / monolike	kg CO ₂ -eq/m ²	4,12	3,85	5,47	3,00	8,22	6,15
Réalisation des cellules	Kg CO ₂ -eq/m ²	20,52	19,12	27,37	14,82	41,37	30,82
Verre	kg CO ₂ -eq/kg	1,00	1,00	1,03	0,98	1,09	1,05
Verre trempé	kg CO ₂ -eq/kg	0,07	0,07	0,07	0,07	0,08	0,07
Encapsulant (EVA ou équivalent)	kg CO ₂ -eq/kg	2,69	2,65	2,88	2,54	3,25	2,97
Feuille face arrière (PET ou équivalent)	kg CO ₂ -eq/kg	3,71	3,67	3,90	3,56	4,27	3,99
Feuille face arrière (PVF)	kg CO ₂ -eq/kg	20,52	20,37	21,29	19,89	22,86	21,68
Module cristallin	kg CO ₂ -eq/m ² module	4,96	4,75	5,99	4,10	8,10	6,51



Simplified Carbon Footprint (ECS) evaluation, what is it ?



- The manufacturer must provide certain **module performance data** in order to assess the amount of each component Gi consumed
- 33% of recycled silicon from ingots is included systematically
- The kerf loss is fixed at 70μmodule

Carbon footprint simulation tool PPE2 without LCA with Ecoinvent 3.9 Valid only for monocrystalline modules



Orange box: Data to be entered by the user
Grey box: Non-modifiable data

A. Module performance data

Parameter	Unit	Value
Module type	-	Bifacial
Front glass thickness	μm	130.0
Module area	m²	2.0120
Number of cells	-	72.0
Module length	mm	2272.0
Module width	mm	1128.0
Total glass thickness	mm	4.0
Frame thickness	mm	1.1
Backsheet thickness	mm	0.0



B. Module composition inventory

Component	Mass (kg)
Si (MG-Si)	0.72
Polysilicon (poly-Si)	0.72
Ingot	0.72
Brick	0.72
Wafer	2.38
Cells	2.38
Modules	2.56
Glass	25.63
Frame	25.63
Encapsulant (top)	2.71
Encapsulant (bottom)	0.00



C. Origin of production sites

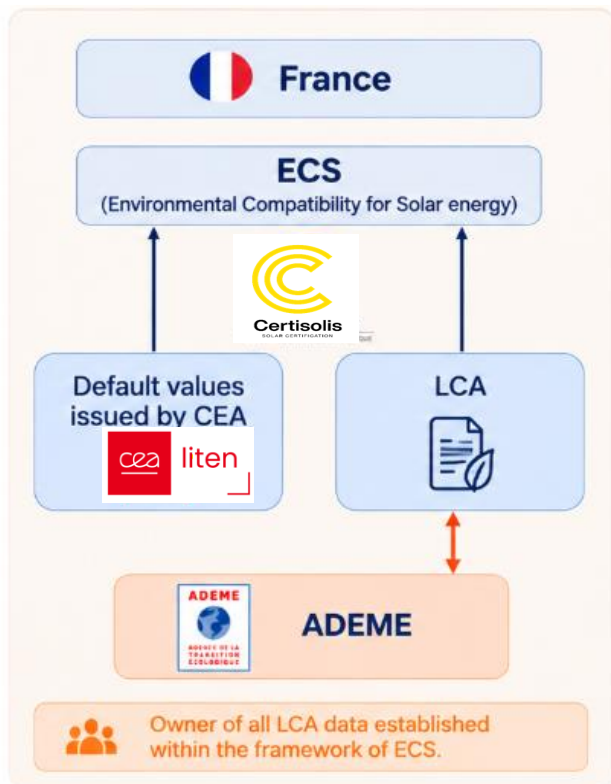
Component	Share (%)	Country
MG-Si (raw silicon)	100%	China
Polysilicon (poly-Si)	87%	China
	33%	Canada
Ingot	100%	Canada
Brick	100%	China
Wafers	100%	China
Cells	100%	China
Modules	100%	China
Glass	100%	China
Frame	100%	China
Encapsulant (top)	100%	China
Backsheet	100%	China



Link to the call for tender:

https://www.cre.fr/fileadmin/Documents/Appels-offres/2024/240814_CDC_PPE2_Batiment_P8.pdf

French Collaboration



-  **France** is the **UNIQUE** country in the world to have **reliable inventory data** for photovoltaics (PV).
-  **ADEME** has decided to use this data in an aggregated manner to publish reliable LCI for PV modules.
-  Collaboration with **CEA** and **CERTISOLIS** to establish the inventory of the different components in the PV module (Poly-Silicon, ingot, wafer...) and with the **Mines Paris tech** for the aggregation.
-  The aggregated inventories will be implemented in the IEA Task 12 PVPS report to update Task 12 2020 report **“Life Cycle Inventories and Life Cycle Assessment of photovoltaic systems”**.

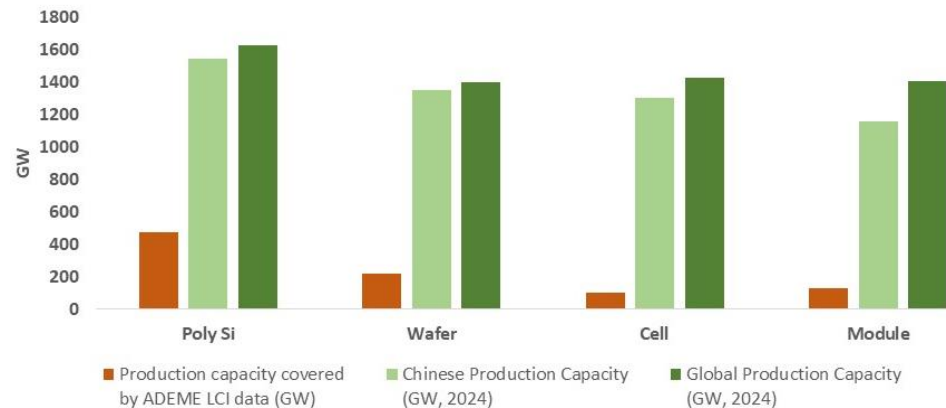
Inventory Data from Industry and French Tender Process

- **83 factory-level LCAs** across the TOPCon PV module supply chain (23 module plants, 60 component plants),
- **High market coverage** compared to previous inventories: 29 % of polysilicon, 16 % of wafer, 7 % of cell and 9 % of module production capacity.
- **All key stages covered:** polysilicon, ingot, brick, wafer, cell and module manufacturing.

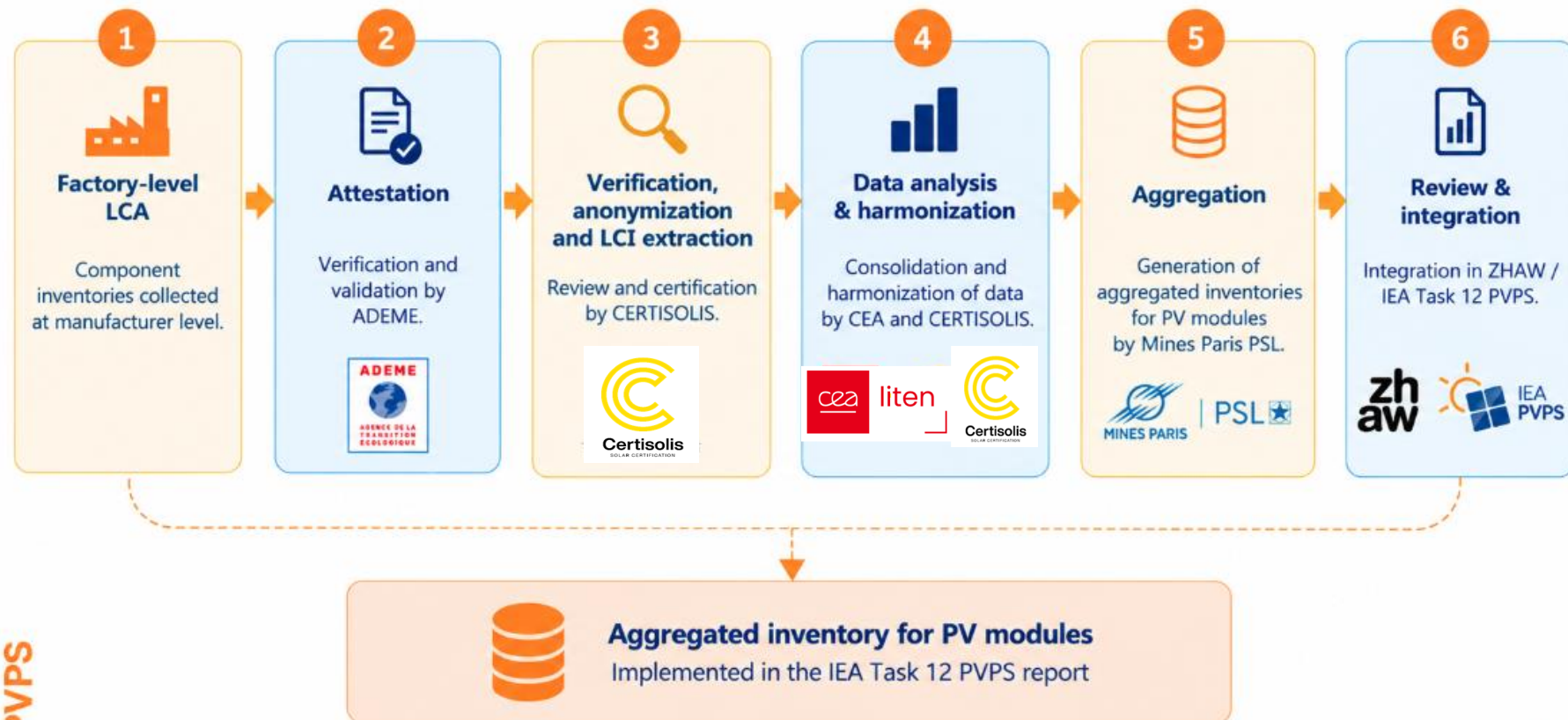
Components	Factories (**)	Data collection period	Production capacity
Polysilicon Siemens	6	2023-2025	256 GW
Polysilicon FBR	5	2022-2025	236 GW
Ingots Type N	9	2022-2025	200 GW
Recycled polysilicon	10	2023-2025	213 GW
Bricks (N Type)	10	2023-2025	213 GW
Wafers (N Type)	9	2023-2025	218 GW
TOPCON LPCVD cells (*)	6	2024-2025	52 GW
TOPCON PECVD cells (*)	5	2024-2025	45 GW
Glass Glass module	12	2023-2025	82 GW
Mono Glass module	11	2023-2025	42 GW
	83		

(*) Passivation process type

(**) 82/83 LCAs are Chinese factories



Steps of the adopted approach to obtain the aggregated inventory



Complete extraction of data from each LCA inventory

This involves extracting the inventories in an **anonymized manner**, materials inputs , energy, packaging, infrastructure, transport, and waste, along with the corresponding quantities **per manufacturer and per component**

Example of extracted LCI data (per 1 m ² of cell output)								
Category	Flow / Parameter	Unit	Manufacturer 1	Manufacturer 2	Manufacturer 3	Manufacturer 4	Manufacturer 5	Manufacturer 6
 Material inputs	Silicon (Si)	kg	...	...	...	...	...	...
	Silver (front contact)	kg	...	...	...	...	...	...
	Aluminium (frame)	kg	...	...	...	...	...	...
	...	...	...	...	...	...	...	...
 Energy	Electricity	kWh	...	...	...	...	...	...
	Natural gas	kWh	...	...	...	...	...	...
	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...
 Packaging	Cardboard	kg	...	...	...	...	...	...
	Plastic (PE)	kg	...	...	...	...	...	...
	Wood (pallet)	kg	...	...	...	...	...	...
	...	...	...	...	...	...	...	...
 Infrastructure	Building hall	m ² -year	...	...	...	...	...	...
	Equipment (metal working)	kg	...	...	...	...	...	...
	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...
 Transport	Truck (road)	tkm	...	...	...	...	...	...
	Ship (sea)	tkm	...	...	...	...	...	...
	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...
 Waste	Waste to treatment	kg	...	...	...	...	...	...
	Hazardous waste	kg	...	...	...	...	...	...
	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...



Material inputs

Raw materials and consumables used per component



Energy

Electricity, heat and fuels consumed



Packaging

Packaging materials (per module or per component)



Infrastructure

Buildings, equipment and facilities



Transport

Upstream and downstream transport (road, sea, air)



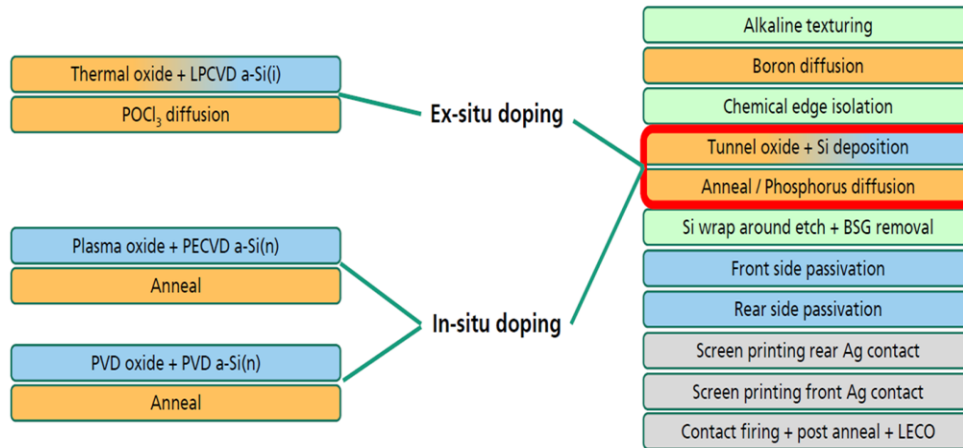
Waste

Waste to treatment, recycling, incineration, landfill, hazardous waste

Definition of the standard process by component



Define **the standard process and material consumption for each component** (polysilicon, wafer, cells...), which helps to later identify which materials are mandatory and provided by the manufacturer, which are secondary, and which may be required but missing and therefore need to be completed.



Key chemical processes and inputs

Examples of chemicals and reactions

- SDE (Saw Damage Etching): KOH or NaOH
- Cleaning: HF/ozone or SC1 (NH₄OH/H₂O₂)
- Texturization: KOH or NaOH
- ...

- For tunnel oxide: $\text{Si} + \text{O}_2 \rightarrow \text{SiO}_2$; or from N₂O
- For poly-Si: SiH₄ (silane)
- For doping (phosphorus diffusion): POCl₃ (Si LPCVD) or PH₃ (Si PECVD)
- ...



It is mandatory to understand the manufacturer's process to distinguish mandatory materials/chemicals.

There is variability in chemical processes depending on the steps, and even for a single step, multiple process options may be used.

PECVD – Plasma Enhanced Chemical Vapour Deposition
LPCVD – Low Pressure Chemical Vapour Deposition
PVD – Physical Vapour Deposition

Harmonization and completion of each inventory



Inventory analysis and **classification of materials as mandatory, optional, or replaceable by another chemical or material**. Such analysis allows for completing and harmonizing the inventories later.

1 Example of materials classification

Material / input	Unit	Classification
Argon	kg	Mandatory
Boron (BCl_3)	kg	Mandatory
Hydrogen peroxide (H_2O_2)	kg	Could be replaced by another chemical
HCl	kg	Optional
Hydrogen Fluoride (HF)	kg	Mandatory
NaOH	kg	Could be replaced by another chemical
Nitrogen (N_2)	kg	Mandatory
Silver paste (front contact)	kg	Optional
Silver paste (back contact)	kg	Optional
...	...	...

Mandatory
(provided by manufacturer)

Optional
(may be required)

Replaceable
(by another chemical/material)

2 Example of completion of each inventory

	Output: 1 m ² of cell					
	Manufacturer 1	Manufacturer 2	Manufacturer 3	Manufacturer 4	Manufacturer 5	Manufacturer 6
Data collection						
Capacity	...	...	...	...	...	...
Country	...	...	...	...	...	...
Components characteristics	...	...	...	...	...	...
Material inputs	...	...	...	...	...	...
Silicon (Si)	...	...	...	...	...	...
Silver (front contact)	...	...	...	...	...	...
H_2O_2	...	...	...	...	...	...
HCl	...	...	...	...	...	...
...	...	...	...	...	...	...
Energy	...	...	...	...	...	...
Electricity	...	...	...	...	...	...
Natural gas	...	...	...	...	...	...
...	...	...	...	...	...	...
Packaging	...	...	...	...	...	...
Cardboard	...	...	...	...	...	...
Plastic (PE)	...	...	...	...	...	...
Wood (pallet)	...	...	...	...	...	...
...	...	...	...	...	...	...
Infrastructures	...	...	...	...	...	...
Building hall	...	...	...	...	...	...
Equipment (metal working)	...	...	...	...	...	...
...	...	...	...	...	...	...
Transport	...	...	...	...	...	...
Truck (road)	...	...	...	...	...	...
Ship (sea)	...	...	...	...	...	...
...	...	...	...	...	...	...
Wastes	...	...	...	...	...	...
Waste to treatment	...	...	...	...	...	...
Hazardous waste	...	...	...	...	...	...
...	...	...	...	...	...	...

Definition of the background data



This involves searching for **the background data** and **creating it** if it does not exist in the database

1 Search in the BAFU database

For each material, energy, or process, we search for the most representative activity in BAFU (by name, technology, geography, and time).



BAFU

Activity name	Database	Location	Unit
Hydrogen peroxide, at plant	BAFU 2022	CH	kg
Hydrogen peroxide, production	BAFU 2022	EU	kg
Hydrogen peroxide, 50% solution	BAFU 2022	CH	kg
Hydrogen peroxide, market	BAFU 2022	GLO	kg
...	...	...	...



Activity found

Use the most relevant BAFU activity.

2 Creation of a new activity if it does not exist

If no suitable activity is found, a new activity is created in BAFU, based on available data (e.g. literature, industry data) and consistent with BAFU modelling rules.

Example of a newly created activity in BAFU

Activity information		Output: 1 m ² of cell
Name	Hydrogen peroxide, production, market for	
Database	BAFU (new activity)	
Location	CH	
Unit	kg	
Inputs		
Anthraquinone	kg	x
Hydrogen	kg	x
Oxygen	kg	x
Electricity, medium voltage	kWh	x
Water	kg	x
...	...	...
Outputs		
Hydrogen peroxide (H ₂ O ₂)	kg	1
...	...	...



The new activity is built following BAFU methodological guidelines.



All assumptions and data sources are documented for transparency and future updates.

Aggregation of the inventories

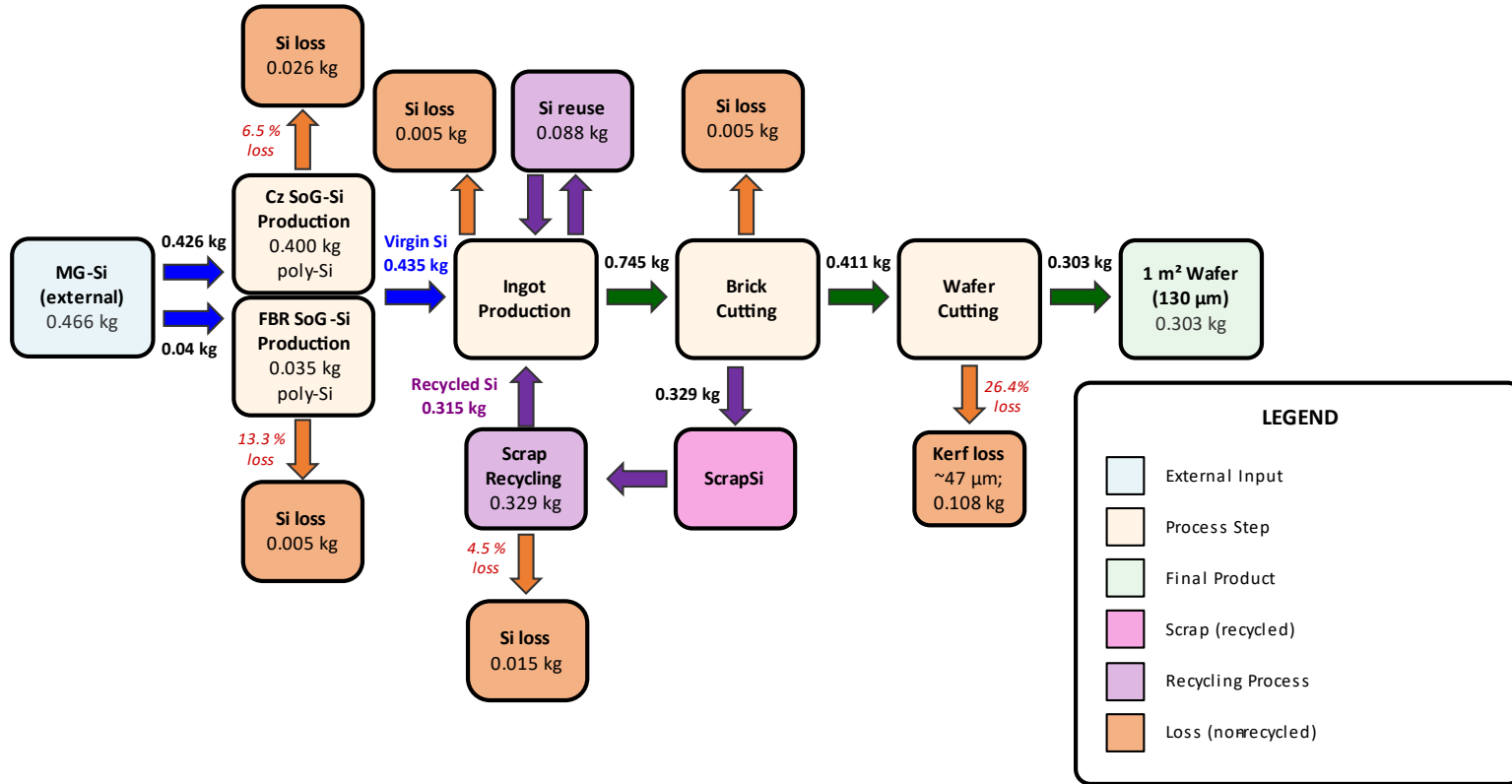


This involves **aggregating the data** to obtain a single aggregated inventory per component, including an analysis of uncertainty and potential variability.

Example of aggregated LCI data (per 1 m² of cell output)

Category	Flow / Parameter	Unit	Aggregated inventory	Manufacturer A	Manufacturer B	Manufacturer C	Manufacturer D
 Material inputs	Silicon (Si)	kg	y	-	-	-	-
	Silver (front contact)	kg	y	-	-	-	-
	Aluminium	kg	y	-	-	-	-
	...	-	y	-	-	-	-
 Energy	Electricity	kWh	y	-	-	-	-
	Natural gas	kWh	y	-	-	-	-
	...	-	y	-	-	-	-
 Packaging	Cardboard	kg	y	-	-	-	-
	Plastic (PE)	kg	y	-	-	-	-
	Wood (pallet)	kg	y	-	-	-	-
	...	-	y	-	-	-	-
 Infrastructure	Building hall	m ² ·year	y	-	-	-	-
	Equipment (metal working)	kg	y	-	-	-	-
	...	-	y	-	-	-	-
 Transport	Truck (road)	tkm	y	-	-	-	-
	Ship (sea)	tkm	y	-	-	-	-
	...	-	y	-	-	-	-
 Waste	Waste to treatment	kg	y	-	-	-	-
	Hazardous waste	kg	y	-	-	-	-
	...	-	y	-	-	-	-

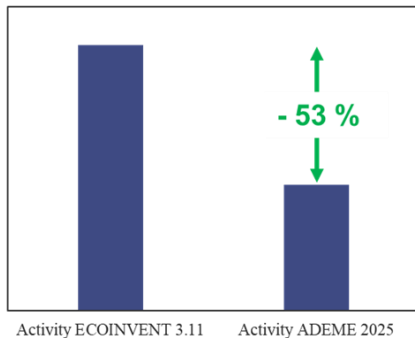
Mass balance



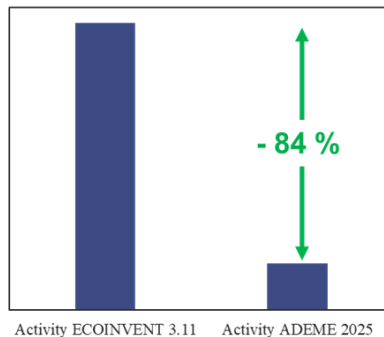
Comparative analysis



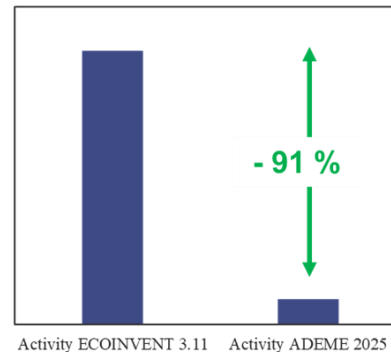
Polysilicon activity
GWP (kgCO₂éq/Kg)



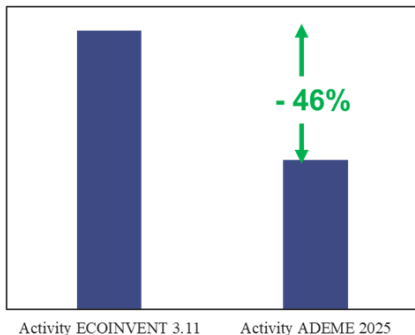
Ingots CZ activity
GWP (kgCO₂éq/Kg)



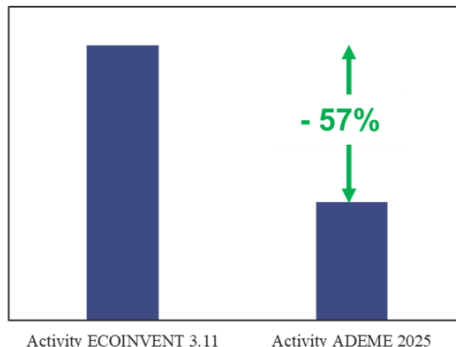
Wafer activity
GWP (kgCO₂éq/m²)



Cell activity
GWP (kgCO₂éq/m²)



Module activity
GWP (kgCO₂éq/m²)



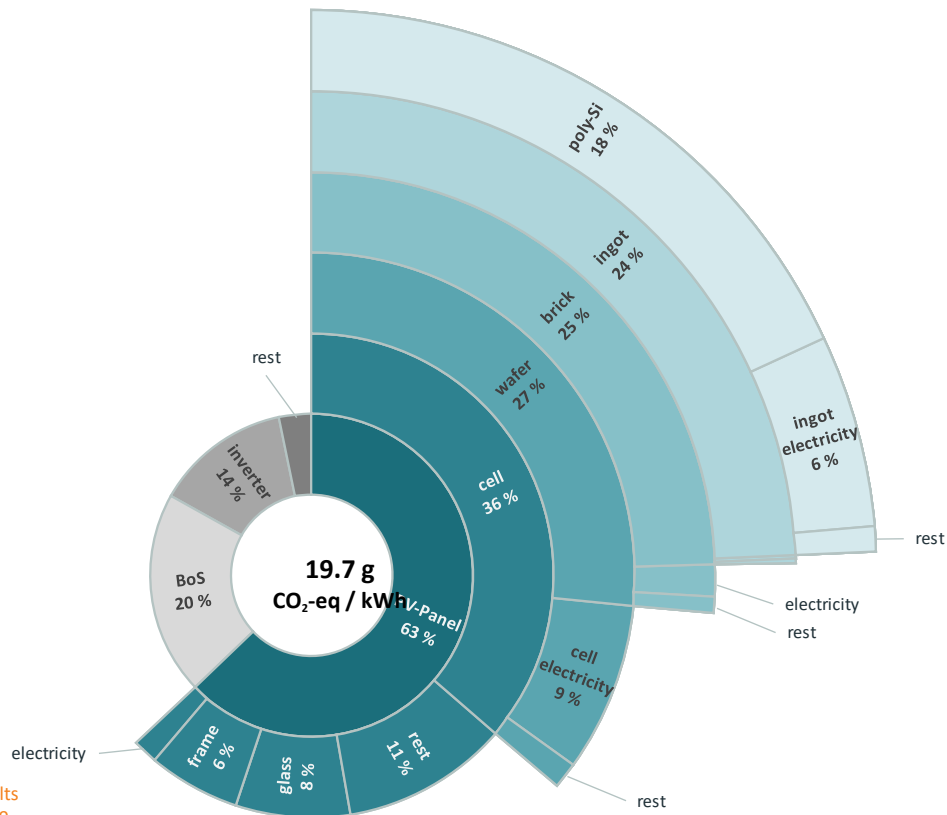
Significant reduction of the carbon footprint of the different component with the new update due to the technological evolution of the processes in the PV field

Supply Chain Contributions to Climate Impact of Electricity from PV System: Residential, mono-Si, 1000 kWh/kWp (e.g. Central Europe)



total mono-Si system GHG emissions
19.7 g CO₂-eq / kWh

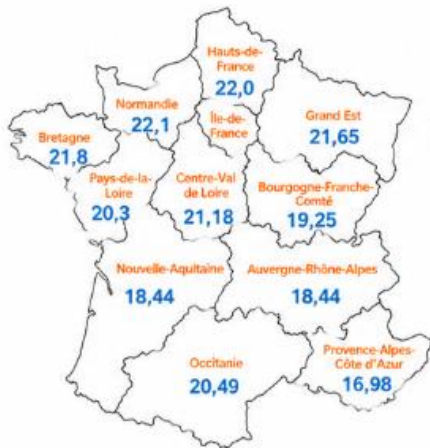
mono-Si module GHG emissions
12.4 g CO₂-eq / kWh



New reference value for Solar energy in France

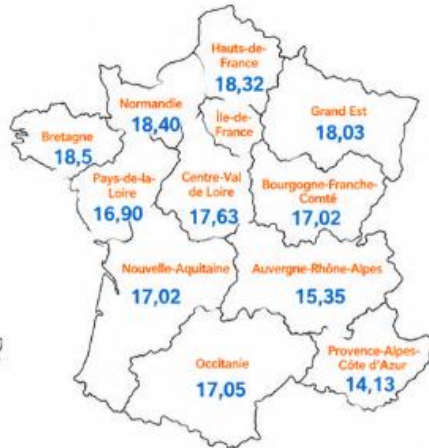


Utility scale **monofacial**



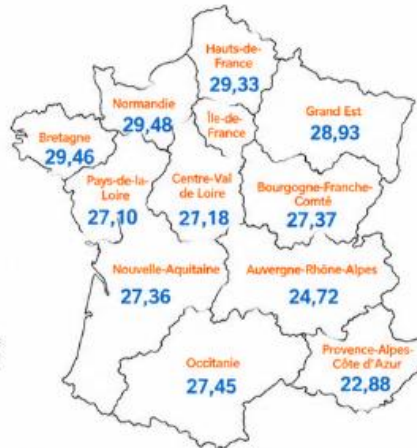
Average : 21,67 gCO₂eq/kWh

Utility scale **Bifacial**



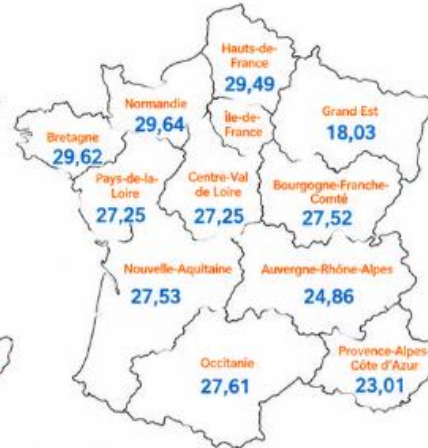
Average : 18,22 gCO₂eq/kWh

C&I



Average : 29,33 gCO₂eq/kWh

Résidentiel



Average : 29,50 gCO₂eq/kWh



ADEME has published a **press release** to update the reference carbon footprint value for photovoltaic electricity in France, which decreases from **43** to an average of **25 gCO₂eq/kWh** (new data range: 20–30 gCO₂eq/kWh).

Read the ADEME press release:

<https://www.ademe.fr/presse/communiqu%C3%A9-national/photovolta%C3%9Cue-une-collaboration-fran%C3%A7aise-in%C3%A9dite-actualise-les-donn%C3%A9es-de-r%C3%A9f%C3%A9rence-et-confirme-la-baisse-de-l'empreinte-carbone-de-l'electricit%C3%A9-solaire/>

Conclusion



IEA PVPS Task 12 delivers the most **comprehensive update to public PV LCI data** in over a decade.



Verification, anonymization, harmonization and aggregation processes both ensure **data quality** and protect anonymity of data providers.



The LCI data and the report will be published **open-source** this summer via IEA PVPS Task 12.



These inventories will support **LCA, hotspot analysis and ecological improvement** along the PV supply chain.

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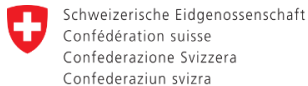
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