

## Life Cycle Inventories of Photovoltaic Systems

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The Technical Report is available for download from the IEA-PVPS website [www.iea-pvps.org](http://www.iea-pvps.org).

## Executive Summary

Life cycle assessment (LCA) is a structured method for quantifying material and energy flows, emissions, resource use, and associated environmental impacts over the life cycle of products and services. In photovoltaic (PV) systems, robust life cycle inventories (LCIs) are a prerequisite for credible LCA results and are often the main barrier to consistent, transparent, and comparable environmental assessments. One of the core objectives of the International Energy Agency Photovoltaic Power Systems Programme (IEA PVPS) Task 12 (PV Sustainability) is therefore to provide internationally reviewed LCI data for PV technologies and system components, supporting consistent LCA of PV electricity generation across technologies, regions, and applications.

This report updates and expands the previous IEA PVPS Task 12 LCI report published in 2020. It provides updated LCI datasets for selected monocrystalline silicon PV supply chains, including PERC and TOPCon cell technologies, thin-film cadmium telluride (CdTe) PV modules, selected string inverters, and country-specific PV mixes. It also includes LCIs for balance-of-system components, PV module recycling, reference residential, commercial, and utility-scale PV systems, and PV installations. Some datasets from previous editions are retained without substantial update, including multi-crystalline silicon PV, CI(G)S modules, perovskite–silicon tandem PV, Li-ion battery storage, selected mounting structures, and medium-large PV installations in Europe. Users should therefore verify the reference year and update status of each dataset before using the data in comparative LCA studies. Updated LCI data tables are provided in sections **Error! Reference source not found.** and **Error! Reference source not found.**, with electronic versions available at IEA PVPS (<https://iea-pvps.org/research-tasks/pv-sustainability>) and ZHAW (<https://doi.org/10.21256/zhaw-2586>).

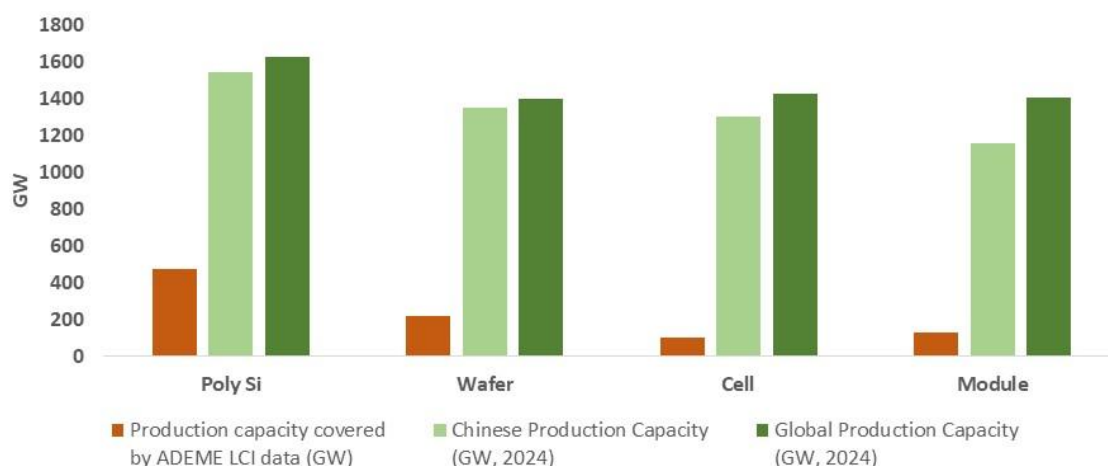
This edition represents a substantial update of the IEA PVPS Task 12 LCI report series. The update is particularly significant for the monocrystalline silicon supply chain, where LCI data are based on a

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large set of LCAs collected in the context of the French PV tender process operated by ADEME between 2022 and 2025. In total, after screening, consistency checks, and exclusion of datasets that were non-coherent or insufficiently representative, 83 LCAs of different factories producing different PV supply chain components across the PV value chain were retained for the final aggregation.

These data cover key supply chain stages from polysilicon, ingot and brick production to wafer, cell, laminate, and module manufacturing. The resulting datasets are aggregated and anonymised to protect confidential company information while enabling public use in LCA.

The market coverage of the updated monocrystalline silicon industry data is high for public PV LCI datasets. Relative to global production capacity, the 83 datasets obtained from ADEME represent approximately 29% of polysilicon production capacity, 16% of wafer production capacity, 7% of cell production capacity, and 9% of module production capacity (see Figure 1).



**Figure 1: Production capacity covered by industry data from French tenders compared against the Chinese and global c-Si production capacity [1; 2]**

The CdTe module datasets were updated using LCI data provided by First Solar and replace the CdTe datasets included in the 2020 report. Because First Solar accounts for more than 90% of global CdTe module production, these datasets can be considered highly representative of the current CdTe PV market.

The quality assurance process differs by dataset type. The monocrystalline silicon datasets benefit from the extensive ADEME/CERTISOLIS/Mines Paris–PSL/CEA workflow described below and from aggregation across many company LCAs. The CdTe dataset is based on primary manufacturer data from the dominant global CdTe producer and were reviewed in the Task 12 process. The inverter and tracker datasets draw on primary or component-level data from selected manufacturers and contributors but should not be interpreted as full market-average datasets.

The LCI presented in this report followed a multi-step quality assurance process behind the updated datasets. For the monocrystalline silicon supply chain, the underlying LCAs were first developed within the French PV tender framework, which requires documented production data, process descriptions, material and energy flows, allocation assumptions, and supporting evidence. CERTISOLIS performed technical and administrative verification of submitted dossiers, including consistency checks of supporting documentation. ADEME then provided the final attestation required for the French tender process; on-site audits on a random subsample of submissions were also conducted to verify procurement flows, manufacturing operations, and supporting records. For the public Task 12 datasets, further data control and aggregation were performed by Mines Paris–PSL, while CEA and CERTISOLIS contributed expert review, analysis, anonymization, and consistency checks.

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The full report and datasets were then reviewed and approved by IEA PVPS Task 12 experts and revised based on comments from international reviewers from research organisations, industry, and public institutions.

This report also introduces a new category of Task 12 LCI data: detailed LCI data based on bottom-up simulations. These datasets, developed by Fraunhofer ISE, represent simulated monocrystalline silicon PERC and TOPCon production for 2024–2025 and include detailed modelling of advanced manufacturing processes, production infrastructure, water management, and waste treatment as validated by industry. They are not equivalent to the industry-average datasets derived from measured production data. Instead, they provide complementary inventories for analysing advanced or leading-edge manufacturing scenarios, process optimisation, and prospective technology development. Users should explicitly state whether they use industry-representative measured data or data from bottom-up simulation.

Several caveats are important for correct interpretation. First, the monocrystalline silicon industry data originate from the French tender system, where carbon performance is an explicit criterion. The underlying datasets may therefore be biased toward lower-carbon supply chains compared with the full global PV market. Second, the data are not all representative of the same year. The monocrystalline silicon data mainly cover 2022–2025, CdTe data cover production years up to 2023, and several not updated datasets originate from older report editions. Third, continuous improvements in PV manufacturing efficiency, material utilisation, energy efficiency, and carbon performance mean that some data may already be conservative relative to the best products currently entering the market.

The main uncertainties in the LCI datasets arise from five sources: variability in manufacturing routes and plant-level performance; regional electricity mixes and upstream supply-chain assumptions; differences in reference years across technologies and components; and incomplete market coverage for BOS components and older technologies. Additional uncertainty arises from assumptions on recycled silicon shares, closed-loop silicon scrap treatment, wafer thickness, kerf losses, cell efficiencies, and module formats. These uncertainties do not undermine the usefulness of the datasets, but they define their appropriate use: the industry-representative measured LCIs are well suited as generic background data, screening datasets, and harmonised reference inventories. For comparative LCAs of specific manufacturers, product lines, or procurement decisions, specific foreground data should be used wherever available.

### Key messages

- **This is the most comprehensive IEA PVPS Task 12 LCI update in more than a decade.** The monocrystalline silicon supply chain update for TOPCon cell technology is based on 83 screened LCAs of different components from the French PV tender process and provides unusually high market coverage for public PV LCI data, including approximately 29% of global polysilicon, 16% of global wafer, 7% of global cell, and 9% of global module production capacity. CdTe data are based on primary data from the dominant global CdTe producer, representing more than 90% of the CdTe module market. Additionally, new LCI data on string inverters have been added.
- **The updated datasets have undergone a robust, multi-step quality assurance process.** For instance, the monocrystalline silicon, the data passed through French tender LCA documentation requirements, CERTISOLIS verification, ADEME attestation, expert aggregation and anonymisation by Mines Paris–PSL, CEA and CERTISOLIS, and final IEA PVPS Task 12 expert review.
- **Users must distinguish between dataset types.** This report includes industry-representative measured LCI data, selected product-line industry data (CdTe modules), retained datasets from earlier report editions, generic BOS component inventories, and—for the first

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time—industry-validated, modelled LCI data for advanced monocrystalline silicon manufacturing. These categories have different appropriate uses and should not be treated as interchangeable.

- **Representativeness is strong but not uniform.** The monocrystalline silicon and CdTe datasets have high credibility and strong market relevance, while BOS datasets and older technology datasets should be used more cautiously as generic inventories. For manufacturer-specific comparative LCA, specific foreground data remain necessary.