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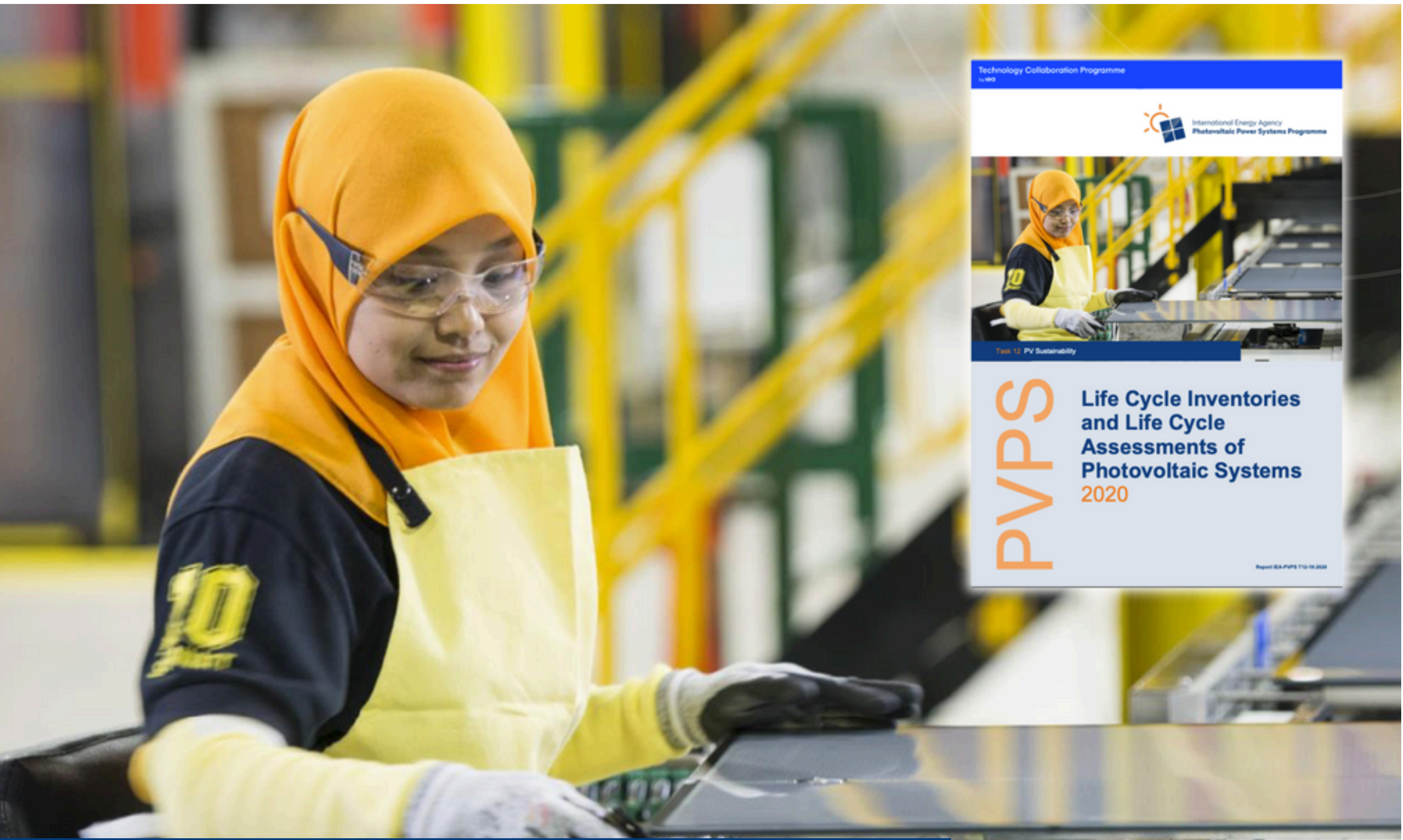
Photovoltaic Power Systems Programme



Task 12 PV Sustainability

PVPS

FACT SHEET

Environmental Life Cycle Assessment of Electricity from PV Systems

2023 DATA UPDATE

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Life Cycle Assessment

PV Life Cycle Assessment (LCA) is a structured, comprehensive method of quantifying and assessing material and energy flows and their associated emissions from:

- 01 **Manufacturing** - resource extraction, raw material production, wafer, cell and panel production
- 02 **Transport** - distribution and storage
- 03 **Installation** - roof mounting and cabling
- 04 **Use** - over a 30 year period and maintenance
- 05 **End of Life** - dismantling, recycling, waste management

PV Scope

The scope of this study represents an **typical residential PV system**:

- 1 kWh AC electricity, produced with a 3 kWp roof-mounted PV system in Europe
- Scope includes PV panel, cabling, mounting structure, inverter and system installation
- 976 kWh/kWp annual production, 1'331 kWh/m2 in-plane irradiation
- Linear degradation: 0.7 %/a [1]
- Service life: panel 30 years, inverter 15 years

This study includes four PV module technologies with the following efficiencies:

1. Cadmium-Telluride (CdTe) 18.4 %
2. Copper-Indium-Gallium-Selenide (CIS / CIGS [2]) 17.0 %
3. Multi-crystalline Silicon (multi-Si, BSF [2]) 18.0 %
4. Mono-crystalline Silicon (mono-Si, PERC / TOPCon [3]) 20.9 %

1 As per current Task 12 LCA methodology (IEA-PVPS T12-18:2020), results can be adjusted by assuming a linear relationship with the degradation rate dependent yield. For a degradation rate of 0.5 %/a simply multiply results by a factor of 0.968; while for a degradation rate of 0.9 %/a multiply results by a factor of 1.053.

2 For multi-Si and CIS/CIGS, no new technology-specific data was available for this update due to the currently very low market shares.

3 Electricity, heat, and silicon demand for mono-Si production have been updated based on current production data from multiple manufacturers.

Payback Time

Non renewable energy payback time is defined as the period required for a renewable energy system to generate the same amount of energy (in terms of non renewable primary energy equivalent) that was used to produce the system itself:

	UNIT	Mono-Si	Multi-Si	CIS	CdTe
NREPBT	year	1.0	1.2	1.2	0.8

Environmental Impacts

The **carbon emissions** associated with generating 1 kWh of solar electricity from PV systems are far lower than the emissions from fossil fuel generators, which can emit up to 1 kg of CO_2 per kWh.

	UNIT	Mono-Si	Multi-Si	CIS	CdTe
Greenhouse gas emissions	g CO_2 eq	35.8 [4]	43.6	35.5	25.2
Resource use, fossil fuels	MJ	0.44	0.52	0.51	0.35
Resource use, minerals and metals	mg Sb eq	5.04	5.30	4.64	5.22
Particulate matter	10^{-9} disease incidences	2.87	3.97	1.34	1.04
Acidification	mmol H^+ eq	0.29	0.36	0.21	0.18
Module efficiency	%	20.9	18.0	17.0	18.4
Data	reference period	2020 - 2023	2019 - 2021	2010 / 2020	2020 - 2022

4 Contributions of PV modules: 20.2 g CO_2-eq (56 %); inverter: 9.9 g CO_2-eq (28 %); rest: 5.8 g CO2-eq (16 %)

Environmental Impact Changes

Changes in the environmental impacts compared to 2021 systems are shown in the table below. Percentages above 100 % are the result of an increase in environmental impact, while percentages below 100 % reflect a decrease in impact compared to the previous data.

	Mono-Si	Multi-Si	CIS	CdTe
Greenhouse gas emissions	83 %	99 %	100 %	99 %
Resource use, fossil fuels	87 %	99 %	100 %	99 %
Resource use, minerals and metals	97 %	100 %	100 %	100 %
Particulate matter	74 %	102 %	109 %	108 %
Acidification	80 %	99 %	100 %	99 %
Reference period	2020 - 2023 (2019 - 2021)	2019 - 2021 (2019 - 2021)	2010 / 2020 (2010 / 2020)	2020 - 2022 (2019 - 2020)

Key Changes Compared to 2021 Data

Mono-Si PV panels

- increased panel efficiency (leading to a decrease in life cycle environmental impacts)
- decreased kerf loss / reduced poly-Si demand (leading to a decrease in LC impacts)
- lower electricity and thermal energy demand for solar grade silicon, wafer, cell and panel manufacture (leading to a decrease in LC impacts)

CdTe PV panels

- increased panel efficiency (decrease in impacts)

All technologies

- new versions of life cycle assessment methods (minor deviations in impacts)

Evolution of Greenhouse Gas Emissions over Time for Mono-Si PV Systems

The table below shows the **change in greenhouse gas emissions** from electricity produced by a residential rooftop PV system in Switzerland using mono-crystalline module technology. The reduction in emissions is due to increases in efficiency and improvements in the manufacturing process.

	UNIT	1996	2003	2007	2014	2016	2020	2021	2023
Greenhouse gas emissions	g CO2 eq/kWh	121	72	76	80	107	43	43	36
Module efficiency	%	13.6	14,8	14.0	14.0	15.1	19.5	20.0	20.9
Annual yield	kWh/kWp	862	882	922	922	882	976	976	976

Task 12 Objectives

- Quantify the environmental profile of PV in comparison to other energy technologies;
- Define and address environmental health & safety and sustainability issues that are important for market growth.

Task 12 sub tasks:

1. Circular Economy (CE)
2. Life Cycle Assessment (LCA)
3. Ecosystem Integrated PV (ecoPV)
4. Broader Sustainability Aspects (BSA)

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For more details, see the accompanying slide deck.
Download 2020 full LCI report **here**.
Download previous fact sheet version **here**.
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