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Environmental impacts of CIGSe thin-film PV

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Wädenswil, ZHAW University

Consortium

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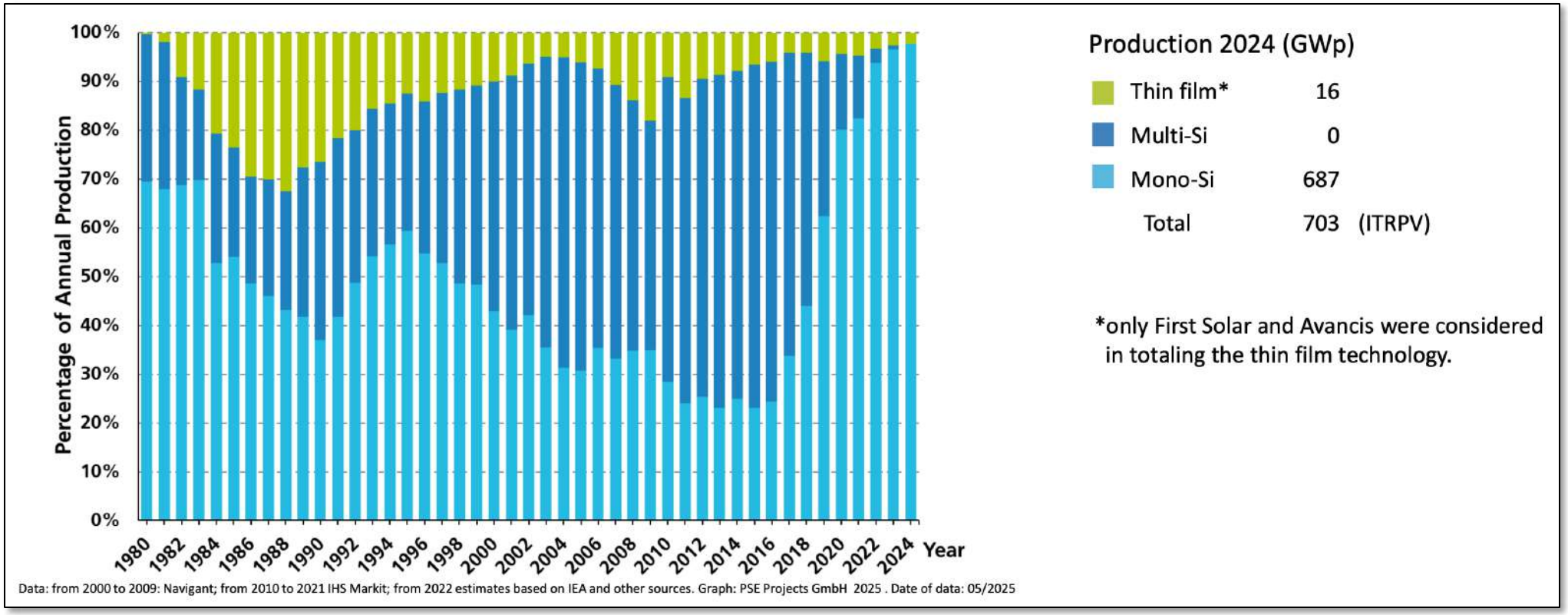
Market for thin-film PV

Even though Mono-Si dominates the market, thin-film PV still has unique applications and footprints



Photovoltaics Report, Dr. Simon Philipps, Fraunhofer ISE und Werner Warmuth, PSE Projects GmbH | Fassung vom 29. Mai 2025

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What is CIGSe PV?

CISe	**CIS**	**CGSe**	**CGS**	**CIGSe**	**CIGS**
$CuInSe_2$	$CuInS_2$	$CuGaSe_2$	$CuGaS_2$	$Cu(In,Ga)Se_2$	$Cu(In,Ga)S_2$

$Cu(In_{1-x}Ga_x)(S_ySe_{1-y})_2$ absorber most often used as **$Cu(In_{0.7}Ga_{0.3})Se_2$**

https://midsummer.se

https://midsummer.se

https://midsummer.se

https://www.avancis.de

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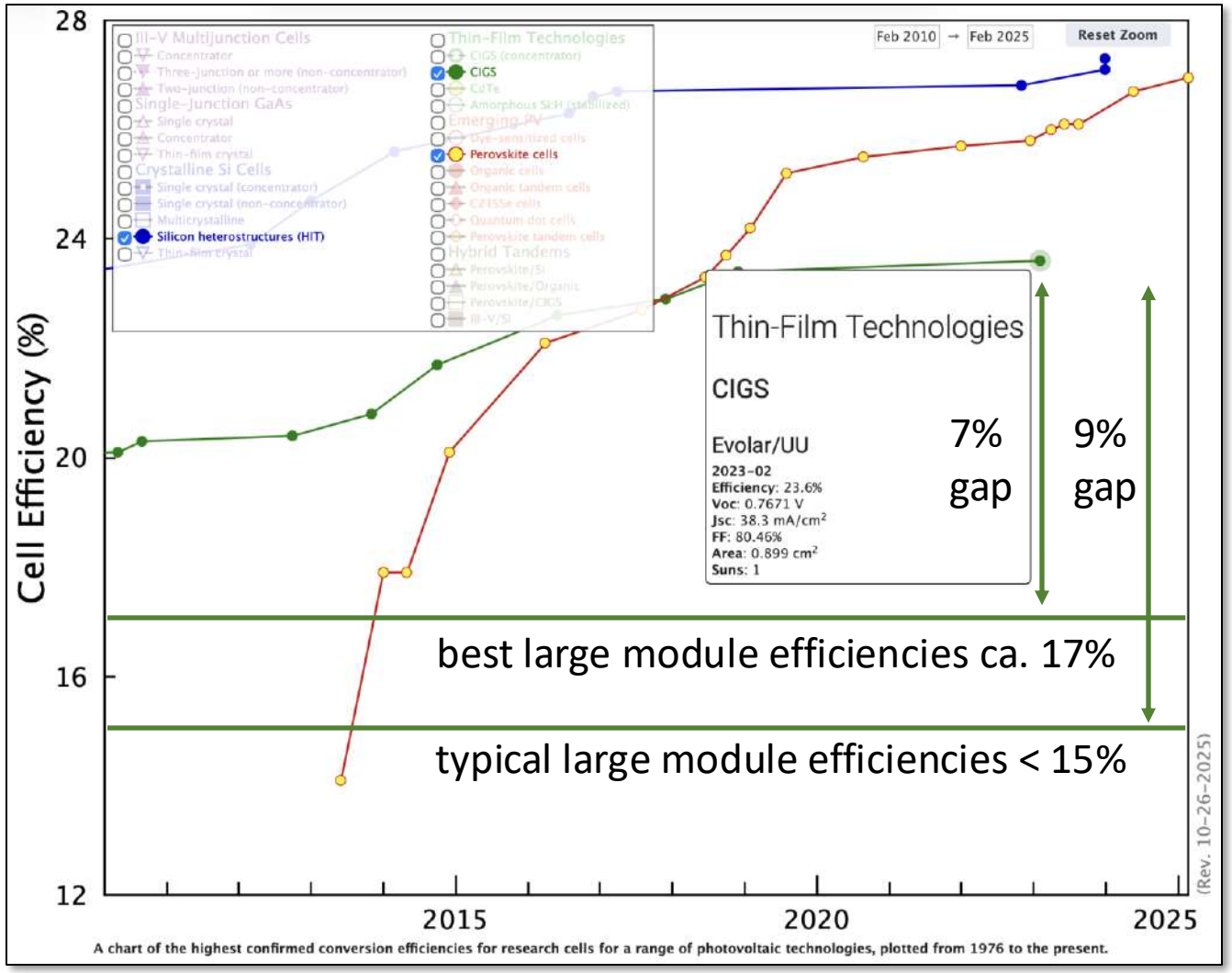
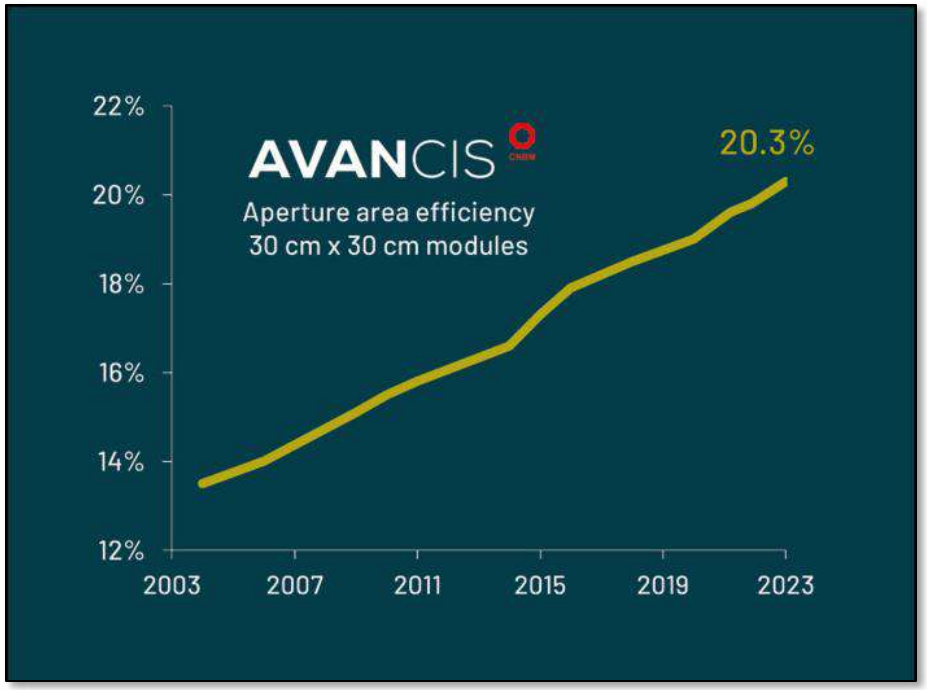
CIGSe module efficiencies and weights



https://www.nrel.gov/pv/interactive-cell-efficiency



Efficiency is not the only key parameter:

- Typical Mono-Si 10 kg/m²
- Best Mono-Si 7.2 kg/m²
- CIGSe glass-free 2.9 kg/m²
- Best CIGSe glass-free 1.7 kg/m²

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Reference CIGSe glass modules

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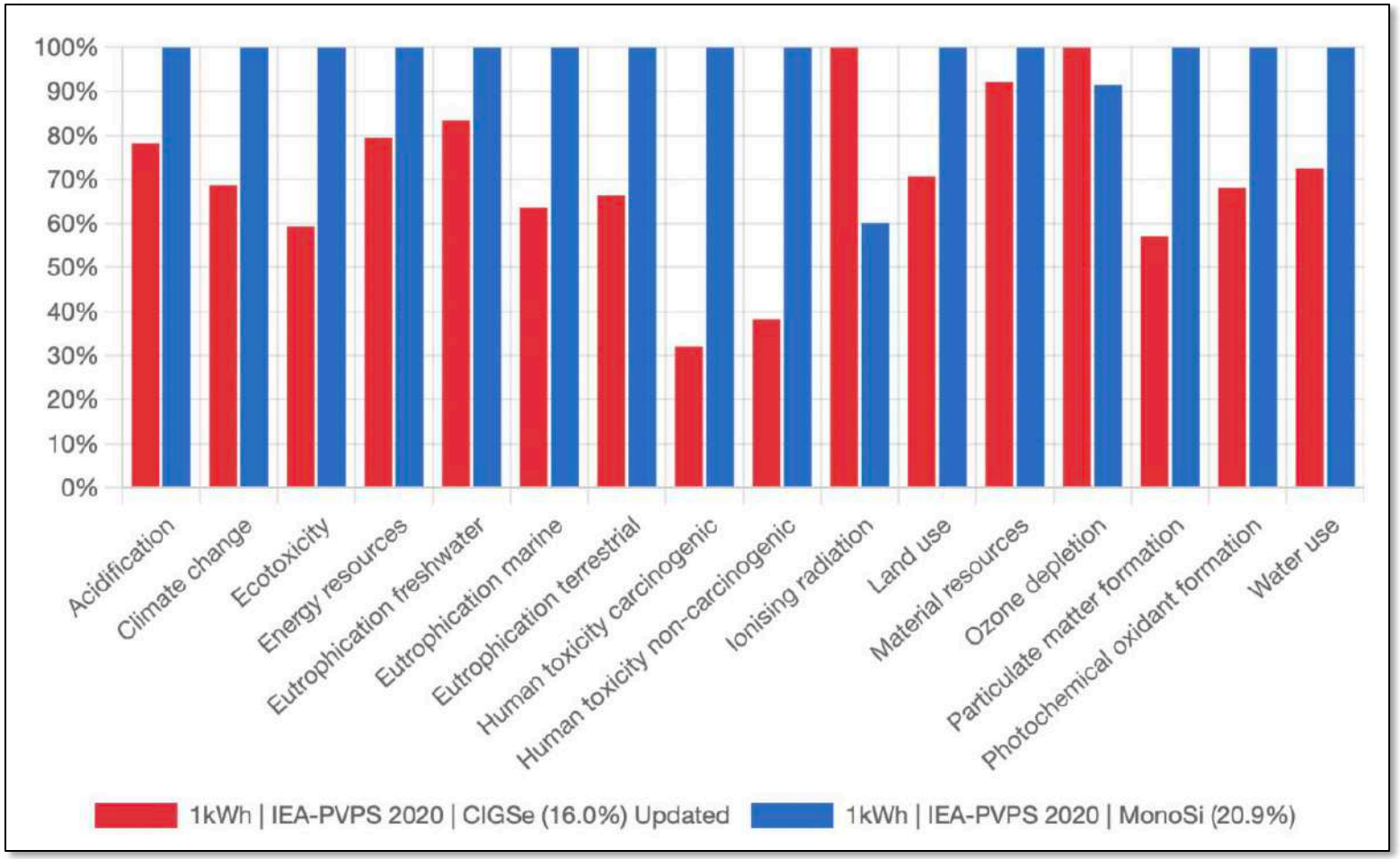
IEA-PVPS 2020 Mono-Si vs. CIGSe (updated)

- Preliminary updated data for CIGSe indicates lower impacts than Mono-Si, but magnitude depends on deposition process and grid location
- Often no large hot spot between CIGSe and Mono-Si observed
- Newer values for Mono-Si exist, but will not induce new hotspots
- Reasons are high contributions from inverter, glass, mounting



IEA-PVPS 2020 processes connected to ecoinvent 3.11 and using EF 3.1 method

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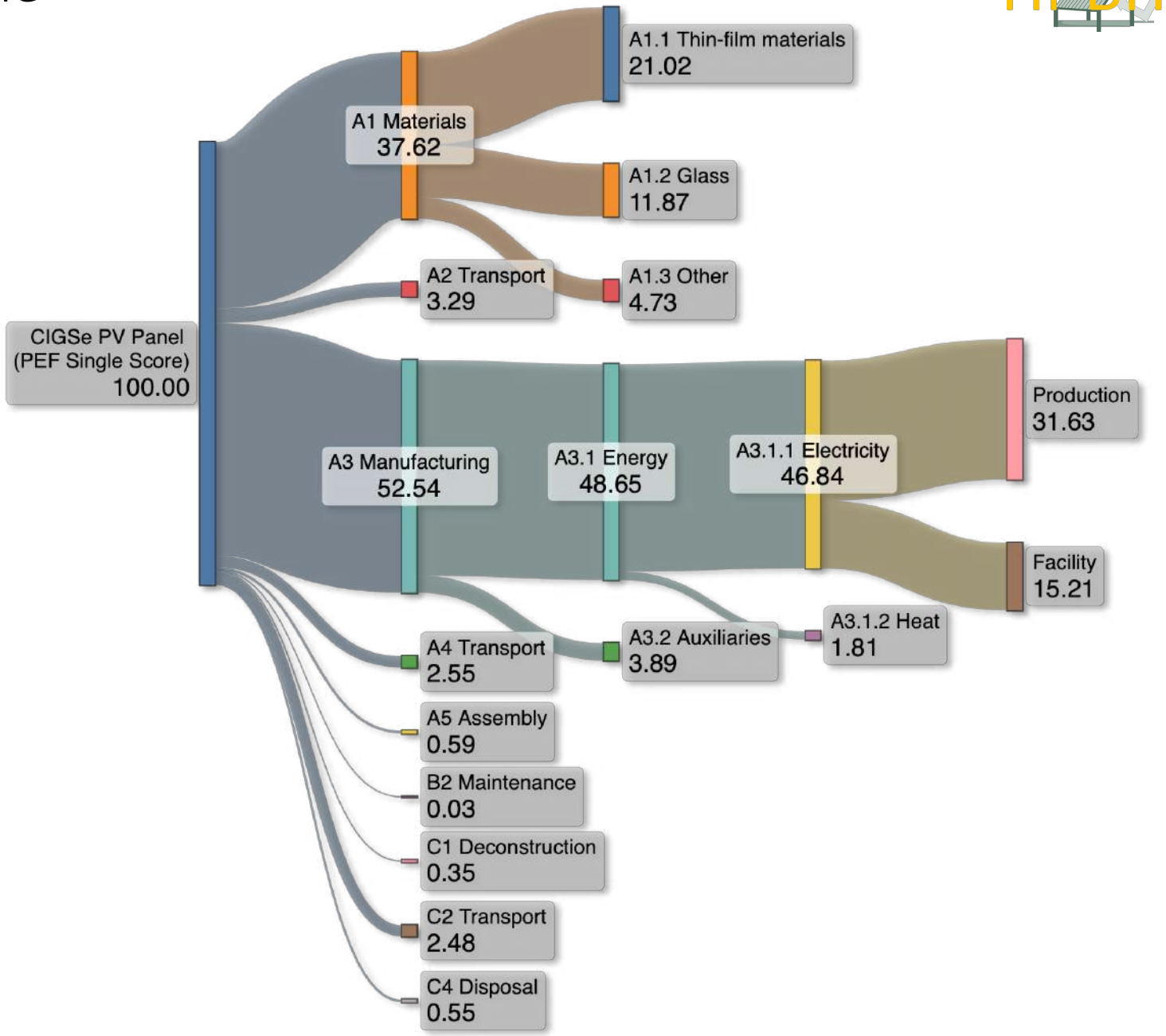
Updated standard CIGSe module

Relative EF 3.1 single score contributions:

- Resource use impacts for thin films
  → absorber thickness reduction
- Climate change impacts for glass
  → no glass or thinner glass
- Climate change impacts for electricity
  → grid with low carbon footprint
  → lower energy demand from machinery



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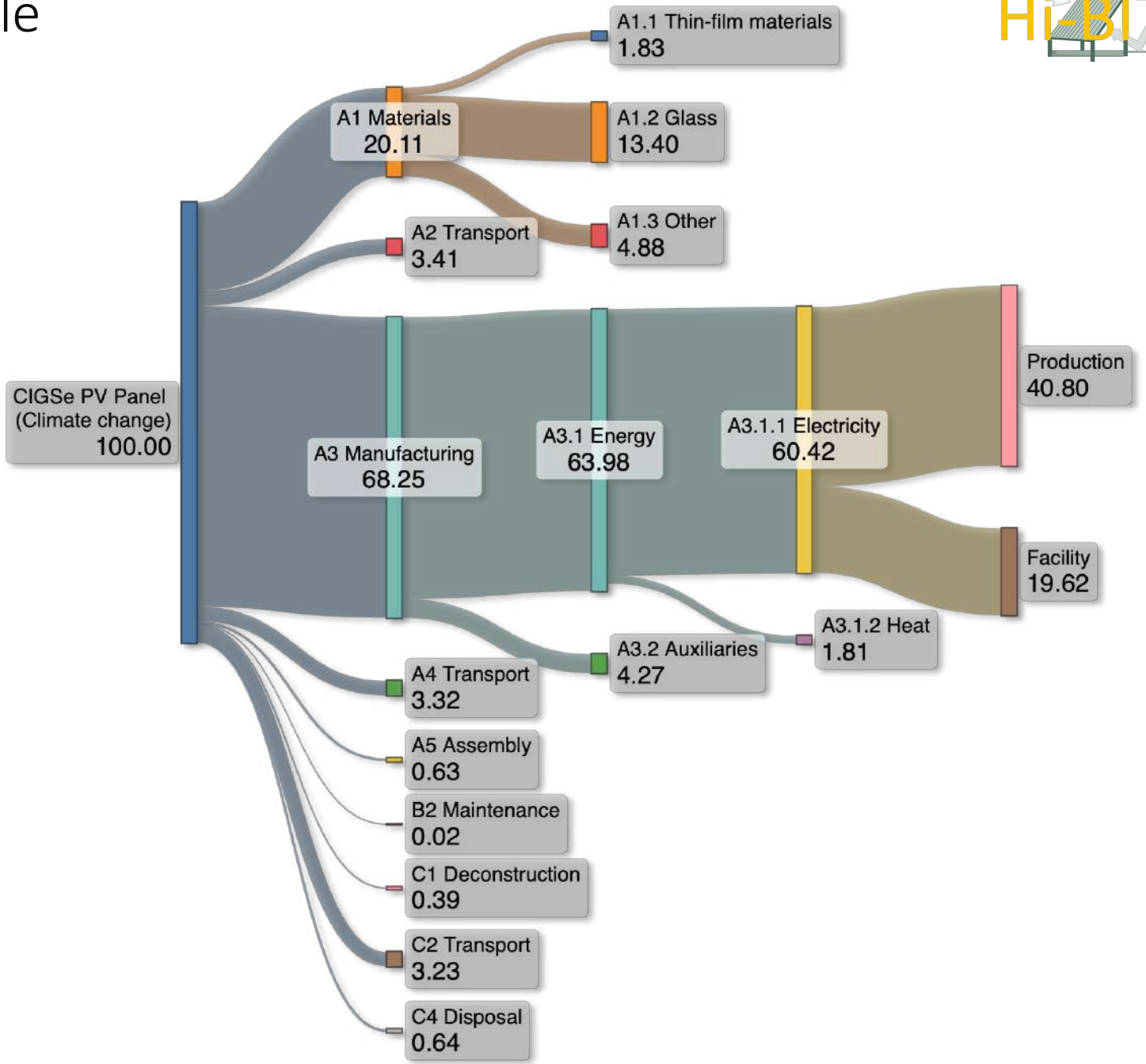
Updated standard CIGSe module

Relative contributions to Climate change:

- Thin-film materials do not significantly contribute to greenhouse gas emissions
- Nearly all climate change impacts from glass and from manufacturing energies



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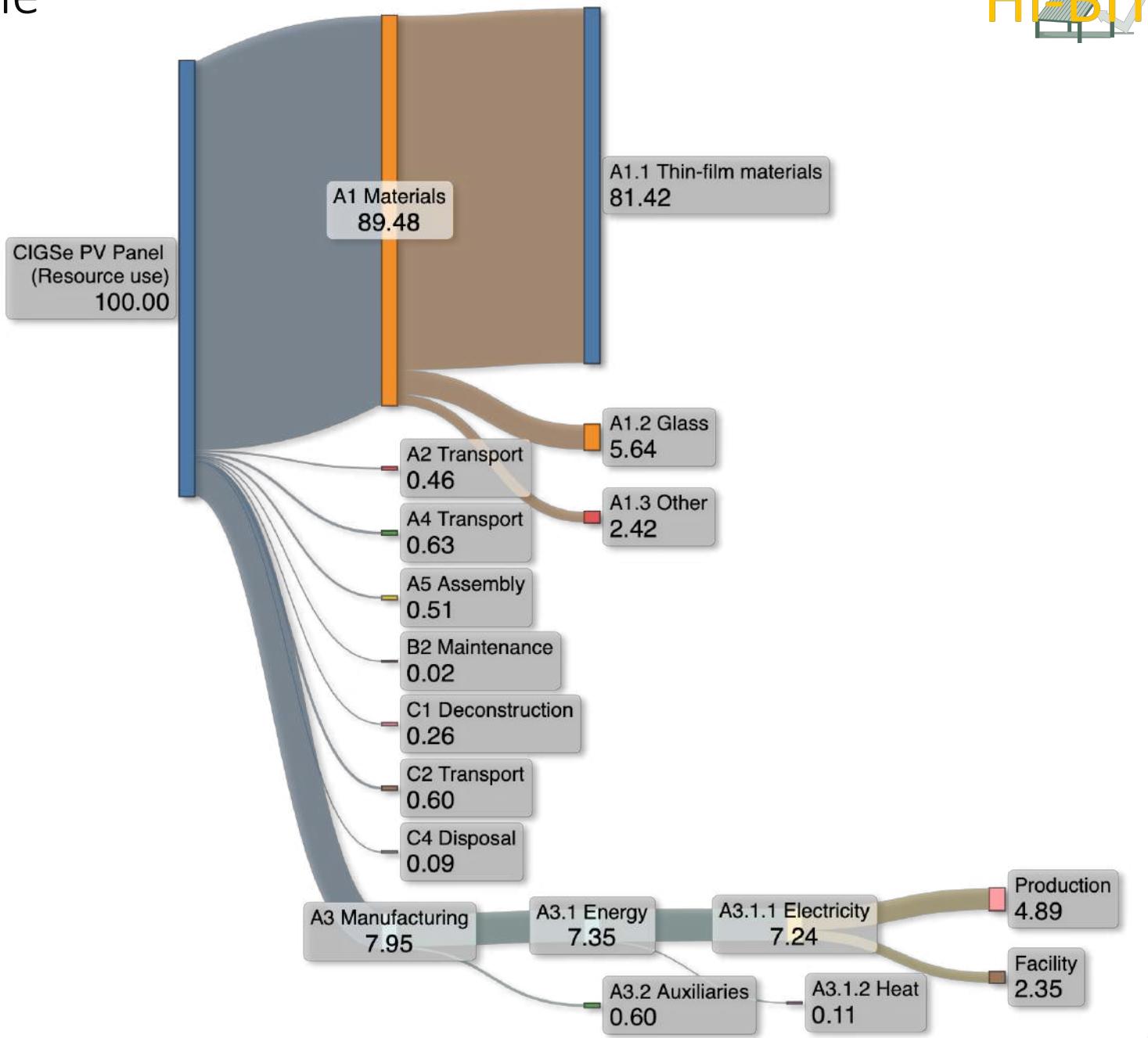
Updated standard CIGSe module

Obviously thin-film materials contribute the most to resource use (ADP) impacts:

- Gallium is EU critical raw materials due to dependence on China (assessment with EU Material Criticality Indicator possible)
- Nowadays less than 0.5 mg of Ga per 1 m^2 possible → 4 tons per GW_p (e.g. 13% here)
- CIGSe market far away from Ga shortage, but dependence on supply from China (> 90% of world market share)



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Commercial CIGSe modules with very low carbon footprint

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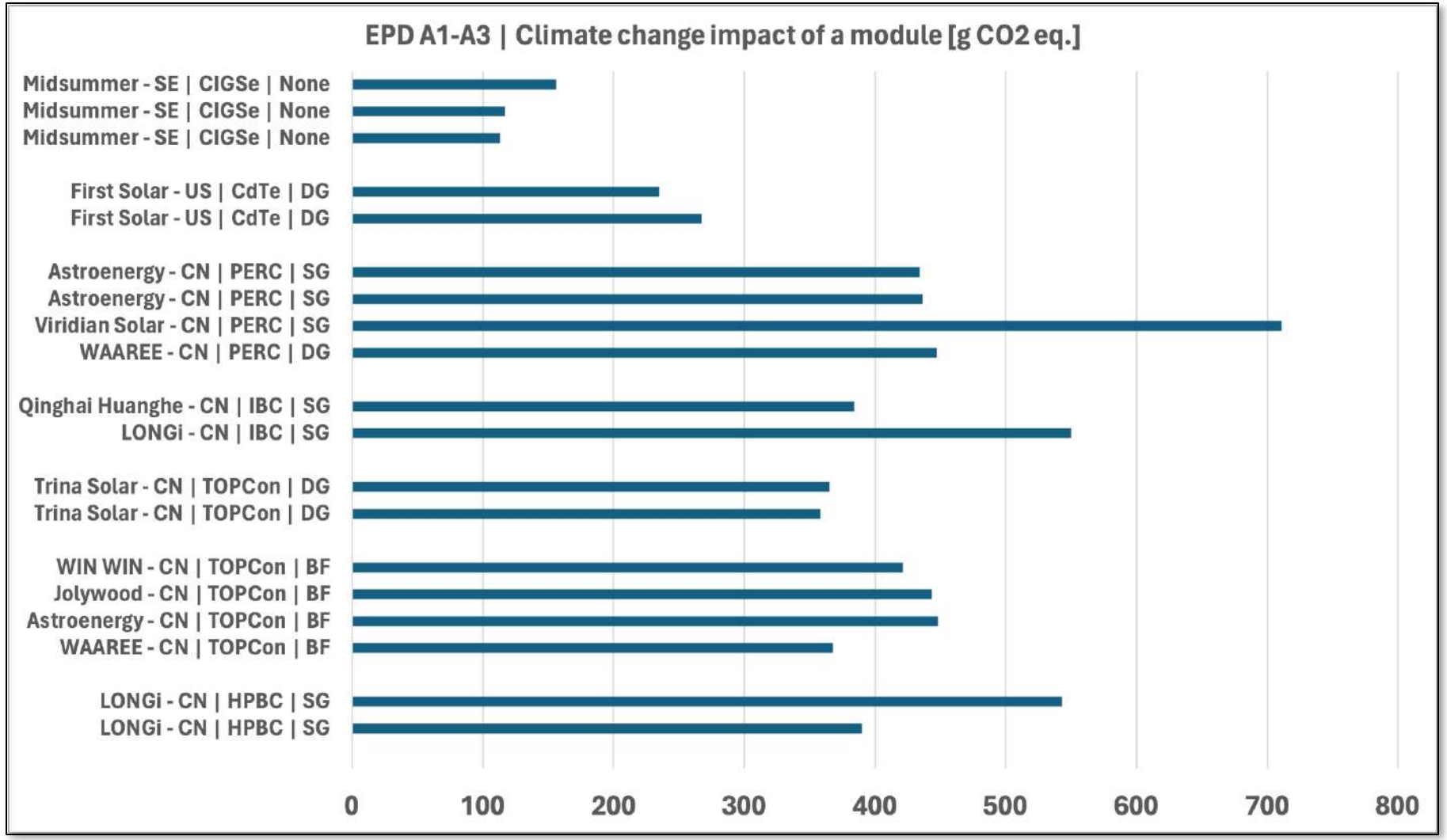
Results from EPD International

With new efficiencies of 13.1% Midsummer is currently below 100 g CO2 eq. per Wp.



IES EPD results A1-A3 with naming "Supplier - Location | Technology | Single glass SG, Double glass DG, Bifacial BF double glass" for each EPD

How is it possible?

- no glass
- thinner absorber
- low energy demand
- SE electricity grid
- (no mounting)

→ less than 20 g CO2 eq. per kWh to the grid achieved

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Key data of flexible CIGSe PV (Midsummer)

Key Parameters and Key Data (2023 updates shown in orange color)

Update 2023	Unit	mono-Si (1)	multi-Si	CIS	CdTe
module efficiency	%	20.9	18.0	13.1	18.4
wafer thickness	µm	160	172.5	2 + ca. 120	
kerf loss	µm	57	65	n.a.	n.a.
further losses	µm	3.4	21.4	n.a.	n.a.
glass thickness	mm	3.2	3.2	no glass	2.1 (front) 2.8 (back)
electricity consumption					
- metallurgical grade silicon	kWh/kg	12		n.a.	n.a.
- polysilicon production	kWh/kg	52.3 (electricity) + 11.6 (thermal)		n.a.	n.a.
- Czochralski monocrystal production / casting	kWh/kg	13.5	7.0	n.a.	n.a.
- wafer manufacture	kWh/m²	2.7	5.6	n.a.	n.a.
- cell manufacture	kWh/m²	9.7	17.7	15.4	n.a.
- panel manufacture	kWh/m²	3.6	7.6 (2)	14.8	19-23
year of key production and market data		2019 - 2023	2019 - 2021	2019-2021	2020 - 2022

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(1) mono-Si technologies: PERC / TOPCon
(2) Change due to harmonisation of calculation.
(3) 2010: production data; 2020: module efficiency

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(steel)

https://iea-pvps.org/wp-content/uploads/2024/05/Slides_IEA-PVPS-T12_Fact-Sheet-update-2023_v2.0.pdf

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Thank you for your attention!

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