How Big is the Solar Module Recycling Industry in India?

Sizing the Market, Investment, and Emission Reduction Opportunity

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Annexures

Table A 1 Decade-wise average material intensities for crystalline silicon modules

Material	Intensity (gm/W)			
	2009-2020	**2021-2030**	**2031-2040**	**2041-2050**
Aluminium	6.695	2.208	1.992	1.903
Glass	48.204	44.863	47.671	48.636
Copper	0.370	0.417	0.379	0.364
Silver	0.004	0.022	0.020	0.016
Silicon	2.177	1.535	1.365	1.282
Tin	0.078	0.053	0.048	0.046
Zinc	0.078	0.0001	0.0002	0.0001
Lead	0.039	0.003	0.003	0.003
Polymer	7.351	5.761	5.130	4.904
Total	**64.997**	**54.862**	**56.609**	**57.155**

Source: Authors' adaptation from Chengjian Xu et al. 2024. "Future material demand for global silicon-based PV modules under net-zero emissions target until 2050." Resources, Conservation and Recycling.

Table A 2 Material composition for thin-film modules

Material	**Composition (%)**
Aluminium	12
Glass	84
Cadmium	0.055
Tellurium	0.06
Copper	0.4
Polymer	3
Others (Tin, zinc, indium and selenium)	0.4

Source: Authors' compilation from IEA. 2022. "Solar PV Global Supply Chains."

Table A 3 Costs assumptions for setting up a c-Si module recycling capacity of 3,600 TPA capacity

Investment parameter	**Amount (INR)**
Land	47,498,400
Construction	23,000,400
Machinery	71,352,000
Compliance	2,001,600
Total	**143,852,400**

Source: Authors' compilation of Kale, Ajinkya and Akanksha Tyagi. 2025. "How Much Does It Cost to Recycle a Solar Module in India?"

Table A 4 Emission factors of all materials in crystalline silicon modules for virgin material pathway

Material	Associated emission factor with extraction and manufacturing (kg CO_2eq./kg)
Aluminium	20.88 (Sripathy 2024)
Glass[a]	0.0486 (Belançon et al. 2022)
Polymer	3.0 (Thunder Said Energy n.d.)
Silicon	69.77 (Yang et al. 2023)
Copper	4.1 (ICA 2021)
Silver[b]	141.9 (UNEP 2013)
Zinc	3.89 (IZA n.d.)

Source: Authors' compilation from multiple reports

Note: These emission factors reflect current market conditions and do not incorporate potential future changes in the electricity grid, such as increased renewable energy penetration expected by 2047.

a) Conversion factor used for kWh/kg to kg CO_2eq./kg is 0.016 kg CO_2/kWh (source of energy here is assumed to be natural gas).

b) Conversion factor used for MJ/kg to kg CO_2eq./kg is 0.0946 kg CO_2/MJ (source of energy here is assumed to be coal).

Table A 5 Emission factors of all materials in thin-film modules for virgin material pathway

Material	Associated emission factor with extraction and manufacturing (kg CO_2eq./kg)
Aluminium	20.88 (Sripathy 2024)
Glass	0.0486 (Belançon et al. 2022)
Polymer	3.0 (Thunder Said Energy n.d.)
Copper	4.1 (ICA 2021)
Tellurium[a]	21.552 (UNEP 2013)
Cadmium[a]	2.289 (UNEP 2013)

Source: Authors' compilation from multiple reports

Note: a) Conversion factor used for MJ/kg to kg CO_2eq./kg is 0.1347 kg CO_2/MJ (source of energy here is assumed to be electricity).

Table A 6 Emission factors for crystalline silicon modules for recycling material pathway

Input	Emission factor (kg CO_2eq./kg)
Fuel – diesel	0.074100 (Frischknecht 2020)
Transport of solar waste from source to recycling facility	0.013180 (Frischknecht 2020)
Disposal – to municipal corporation	0.006270 (Frischknecht 2020)
Disposal – to sanitary landfill	0.010038 (Frischknecht 2020)
Electricity used	0.485 (CEA 2024)

Source: Authors' compilation from multiple reports

Table A 7 Emission factors for thin-film modules for recycling material pathway

Input	Emission factor (kg CO_2eq./kg)

Transport of solar waste from source to recycling facility	0.013180 (Frischknecht 2020)
Deionised water	0.000497 (Frischknecht 2020)
Sulfuric acid	0.180600 (Frischknecht 2020)
Hydrogen peroxide	2.211429 (Frischknecht 2020)
Sodium hydroxide	1.491667 (Frischknecht 2020)
Electricity used	0.485 (CEA 2024)
Wastewater generation during production	0.010793 (Frischknecht 2020)
Disposal of inert waste to sanitary landfill	0.010038 (Frischknecht 2020)
Disposal of waste plastic	0.006270 (Frischknecht 2020)

Source: Authors' compilation from multiple reports

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