



Life Cycle Assessment of c-Si Photovoltaic Module Delamination with Hot Knife Technology

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LCA of c-Si module delamination with hot knife technology



- Goal and Scope
 - Assess life cycle environmental impacts of crystalline silicon (c-Si) PV module delamination with hot knife technology. Delamination is the process of separating glass from backsheet.
- Technology and its modelling
 - Process steps of hot knife technology
 - Removal of Junction (J)-box, then cables are removed from the J-box
 - Removal of aluminum (Al) frames
 - Hot knife separation of glass from the 'cells/Ethylene-vinyl acetate (EVA)' backsheet
 - Materials recovered
 - Aluminium (frame)
 - Glass cullets
 - Components sold for further treatment/recovery
 - Copper cables
 - Cells/EVA backsheet
- Allocation of efforts and emissions based on relative revenues of treatment service, aluminium, glass, copper cables and cells/EVA/backsheet

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3 kWp c-Si PV system, mounted on a slanted roof, Recycling JP		Production	Treatment	Total	Treatment
		kg PV module			% of Total
Particulate matter	kg PM2.5 eq	1.96E-02	2.09E-05	1.96E-02	0.1%
Freshwater ecotoxicity	CTUe	5.40E+01	8.11E-02	5.41E+01	0.1%
Human toxicity, non-cancer effects	CTUh, n-c	5.04E-06	9.41E-09	5.05E-06	0.2%
Human toxicity, cancer effects	CTUh, c	3.63E-07	7.15E-10	3.64E-07	0.2%
Mineral, fossil & renew. resources	kg Sb eq	4.09E-03	7.27E-07	4.09E-03	0.0%
Climate change	kg CO2 eq	1.72E+01	5.70E-02	1.73E+01	0.3%

Upper table: Environmental impacts of delamination process adds less than 0.3% of impacts caused by manufacturing (production).

Characteristics of the PV system:

- Residential scale, pitched roof.
- Average annual yield over lifetime: 975 kWh/kWp (incl. degradation).
- Module lifetime: 30 years.
- Inverter lifetime: 15 years.

Impact category	c-Si PV module
Particulate matter	7.5%
Freshwater ecotoxicity	16.2%
Human toxicity, non-cancer effects	10.4%
Human toxicity, cancer effects	1.9%
Mineral, fossil & renew. resources	20.6%
Climate change	8.3%

The environmental impacts attributed to the recovered raw materials is between less than 2% and 20% compared to those of primary feedstocks.



- The studied hot knife delamination technology efficiently recovers aluminium and glass and separates the backsheet (containing cells/Ethylene-vinyl acetate (EVA)). Based on measured data from the manufacturer, use of this technology contributes 0.3% or less to the environmental footprint of PV electricity in any impact category. When virgin materials are replaced by recovered materials in new module production, life cycle impacts can be reduced by 80-98% depending on the impact category.
- This technology is now being used in one of the largest commercial scale PV recycling facilities in the world (by ENVIE in Bordeaux, France). Improvements will come through this early experience. Gains in energy and consumables efficiency are expected as this technology is deployed in other applications and upscaled to larger volumes.
- Aspects excluded from this study due to lack of available data include the treatment of copper cables, treatment of the backsheet and the recovery of copper and silver. These processes should be added in a future study.

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