

Article (Supplementary Materials)

Industrial Data-Based Life Cycle Assessment of Architecturally Integrated Glass-Glass Photovoltaics: Supplementary Data

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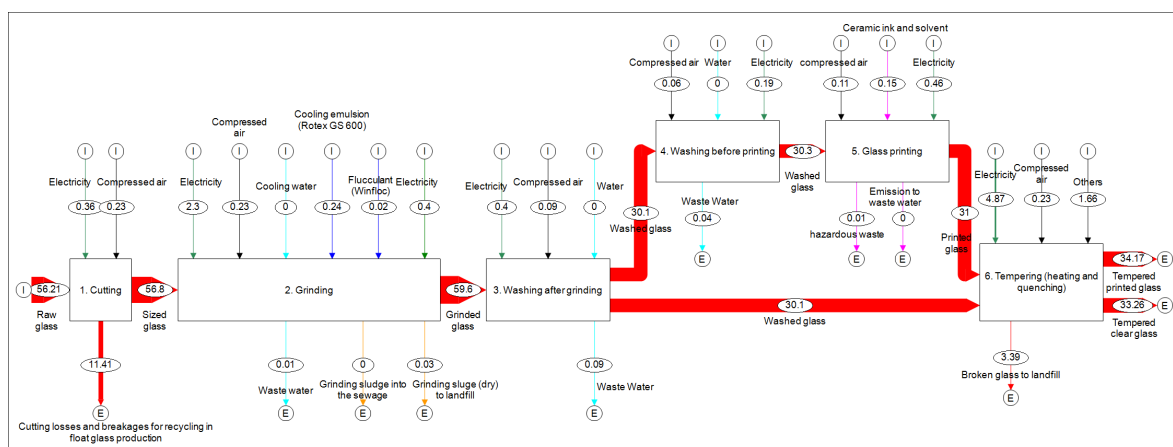


Figure S1. Environmental impact of multi-coloured solar glass production for a PV laminate of size 1.1615 m², expressed in eco-points (kPt). The main input material, raw float glass, dominates with 56.21 kPt, including 14.8kPt due to glass loss, making up for 83% of the total impact. Its impact infact exceeds the total of all other inputs and fabricating processes (11.21 kPt), which contribute 17%. (Data courtesy of Glas Trösch AG, 2018).

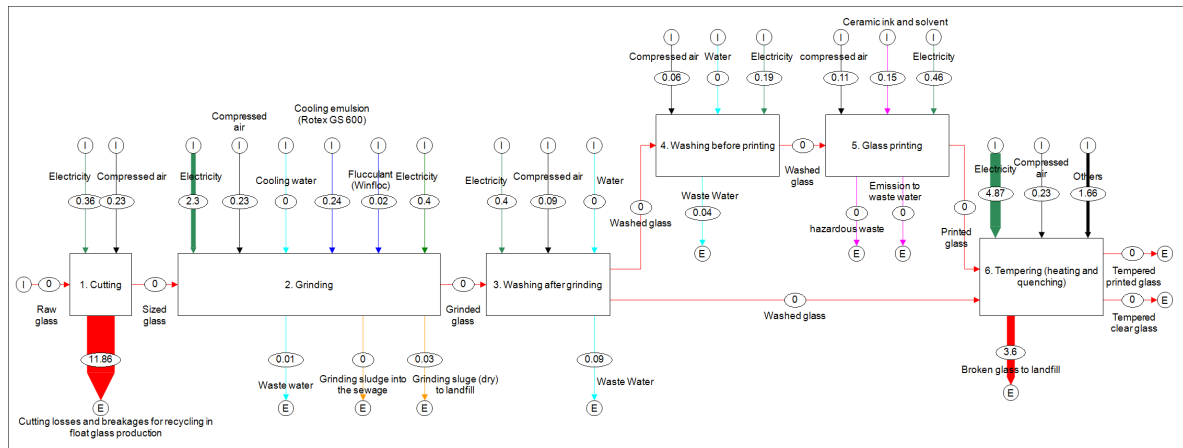


Figure S2. Figure S1 with impact of glass suppressed to highlight that of other flows. Glass losses from cutting and electricity consumption during tempering are significant (11.86 resp. 4.87 kPt), while the net impact of the printing process is merely 1 kPt.

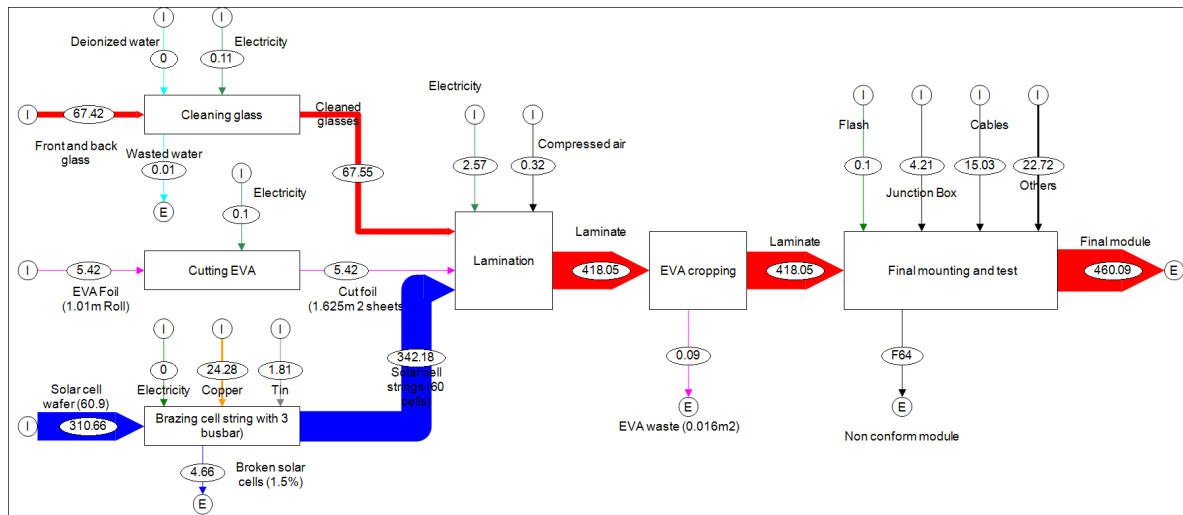


Figure S3. Eco-points (kPt) to produce 1.615 m² of a multi-coloured glass-glass PV laminate with 60 crystalline silicon cells, a junction box and connecting cable. Arrowheads labelled *I* denote and import flow, indicating an input material or energy, while those labelled *E* denote an export flow, indicating a waste or loss. Data was derived from literature and updated with material balance data and measured electricity consumption of the production steps and supporting processes provided by a German PV module manufacturer. (Data courtesy of GES Gebäude- und Energiesysteme GmbH, 2018).

Table S1. Itemised energy and material flows for the production of a clear and multi-coloured solar glass for a PV laminate of size 1.615 m².

Process	Flow	Quantity	Unit	Remark	Data source
Cutting	Raw glass	43.24	kg	Supplied from a European float glass supplier, transportation 300 km by lorry	Ecoinvent 3.4 data, updated with data from Euroglas GmbH ¹ , Glass for Europe ² , and Glas Trösch AG ³
	Cutting losses, breakages for recycling in float glass production	9.12	kg	20% of raw glass, will be recycled in float glass production	Glas Trösch AG ⁴
	Electricity	0.759	kWh		Measured value
	Compressed air	4.264	kWh	Handling device and machine	Estimated value
Grinding	Sized glass	34.12	kg		
	Cooling emulsion	0.01	kg		Glas Trösch AG ⁴
	Cooling water	4.8	kg	Water will be recycled	Estimated 10% of total water consumption according to Glas Trösch AG ⁴
	Flucculant	0.0053	kg	Waste water treatment	For waste water treatment
	Electricity	4.829	kWh	Grinding and water treatment	Measured value
	Compressed air	0.49	kWh	Grinding and water treatment	Estimated value
	Waste water	4.8	kg	After waste water treatment	Estimated from total water consumption according to Glas Trösch AG ⁴
	Grinding sludge into sewage	0.0096	kg	Grinding sludge not removed from waste water	Glas Trösch AG ⁴
	Dry grinding sludge to landfill	0.096	kg	Grinding sludge in waste water	Glas Trösch AG ⁴
Washing after grinding	Ground glass	34.12	kg		
	Deionised water	30.8	kg	High water consumption to remove sludge	Estimated 50% of total water consumption (Material and energy balance from Glas Trösch for 2017)
	Waste water	30.8	kg		Estimated 50% of total waste water according to Glas Trösch AG ⁴
	Electricity	0.8476	kWh	High standby consumption due to under-utilisation	Estimated from nominal power and operating time 2 units × (64kW × 2760 hrs/y) / (production m ² /y) × 1.615 m ²
	Compressed air	0.196	kWh	Handling device and machine	Estimated 10% of total compressed air
	Washed glass	34.12	kg		

¹ ift Rosenheim GmbH, *Umweltdeklaration (EDP) für Flachglas, Einscheibensicherheitsglas, Verbundsicherheitsglas*. Technical Report M-EPD-FEV-002005, Euroglas GmbH, 2017. https://www.glastroesch.ch/fileadmin/content/euroglas/Deutsch/Service/Zertifizierungen/EPD/2018-03-20_Euroglas_M-EPD_FG_ESG_VSG_002_.pdf

² Usbeck, V.C.; Pflieger, J.; Sun, T. *Life Cycle Assessment of Float Glass*. Technical report, Glass for Europe, 2010. <https://www.agc-younglass.com/agc-glass-europe/au/de/pdf/lca/LCA.pdf>

³ Personal Communication with P. Schaad of Glas Trösch AG, <https://www.overleaf.com/3656332281zxqsfrsnbcz> 25.05.2018

⁴ Material and energy balance from Glas Trösch AG for 2017

Table S1. *Cont.*

Process	Flow	Quantity	Unit	Remark	Data source
Washing before printing	Washed glass	16.15	kg		
	Deionised water	14.6	kg		Estimated 25% of total water consumption according to Glas Trösch AG ⁴
	Waste Water	14.6	kg		Estimated 25% of total waste water according to Glas Trösch AG ⁴
	Electricity	0.401	kWh	High standby consumption due to under-utilisation	Estimated from nominal power and operating time $2 \text{ units} \times (64 \text{ kW} \times 2760 \text{ hrs/y}) / (\text{production m}^2/\text{y}) \times 1.615 \text{ m}^2$
	Compressed air	0.116	kWh	Handling device and machine	Estimated 10% of total compressed air
Printing	Washed glass	16.15	kg		
	Ceramic ink and solvent	18.28	g		Glas Trösch AG ⁴
	hazardous waste	5	g		Glas Trösch AG ⁴
	Emission to waste water	0.454	g		Glas Trösch AG ⁴
	Electricity	0.969	kWh	Digital printing, drying, and curing	Glas Trösch AG ³
	compressed air	0.232	kWh	Handling device and machine	
Tempering	Printed glass	16.15	kg		
	Clear glass	16.15	kg		
	Broken glass to landfill	1.82	kg		Glas Trösch AG ^{3,4}
	Electricity	10.237	kWh	Heating and quenching, high standby consumption due to under-utilisation	Glas Trösch AG ³
	compressed air	0.49	kWh	Handling device and machine	Estimated 25% of total compressed air
	Tempered glass	32.3	kg		



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