Environmental Product Declaration

According to ISO 14025

Insulating Glass Products

CARDINAL GLASS INDUSTRIES

Cardinal Glass Industries is considered one of the world's leading providers of superior quality glass products. From the melting of sand to produce clear float glass to the vacuum sputtering of silver to produce low-emissivity coatings.

With this EPD Cardinal intends to support architects and designers with the information they need about the life-cycle environmental impact of Cardinal glass products.

CARDINAL® Glass Industries

Issue Date: 05-27-2020

Valid Until: 05-27-2025

Declaration Number: ASTM-EPD149

DECLARATION INFORMATION

DECLARATION

Program Operator: ASTM International

Company: Cardinal Glass Industries

www.astm.org

www.cardinalcorp.com

PRODUCT INFORMATION

Product Name: Insulating Glass

Product Definition: Double pane and triple pane units separated by spacers and filled with argon; panes can be annealed, tempered or coated

Declaration Type: Business to business

PCR Reference:

- Part A: Calculation Rules for the LCA and Requirements Project Report, (IBU/UL E, V1.2, 06.19.2014)
- Part B: Processed Glass EPD Requirements (UL Environment, 2016)

VALIDITY / APPLICABILITY

Period of Validity: This declaration is valid for a period of 5 years from the date of publication

Geographic Scope: United Sates

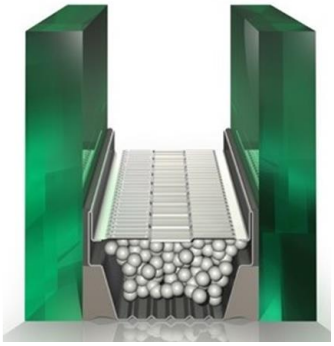
PCR Review was conducted by:

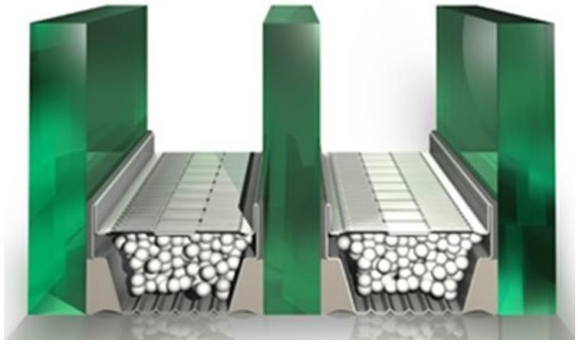
- Thomas P. Gloria, Ph.D., Industrial Ecology Consultants
- Mr. Jack Geibig, Ecoform
- Mr. Bill Stough, Sustainable Research Group

PRODUCT APPLICATION AND / OR CHARACTERISTICS

The primary application is windows and doors.

Technical Drawing or Product Visual





Content of the Declaration

- Product definition and physical building-related data
- Details of raw materials and material origin
- Description of how the product is manufactured
- Data on usage condition, other effects and end-of-life phase
- Life Cycle Assessment results

Verification

Independent verification of the declaration and data, according to ISO 21930:2007 and ISO 14025:2006 ☐ internal x external

This declaration and the rules on which this EPD is based have been examined by an independent verifier in accordance with ISO 14025.

Name: Timothy S. Brooke ASTM International 100 Barr Harbor Dr. West Conshohocken, PA 19428 cert@astm.org	**Date:** 05-27-2020	**Name:** Thomas Gloria, Ph.D. Industrial Ecology Consultants info@industrial-ecology.com	**Date:** 05-27-2020

EPD Summary

This document is a Type III environmental product declaration by Cardinal Glass Industries (Cardinal) that is certified by ASTM International (ASTM) as conforming to the requirements of ISO 21930 and ISO 14025. ASTM has assessed that the Life Cycle Assessment (LCA) information fulfills the requirements of ISO 14040 in accordance with the instructions listed in the referenced product category rules. The intent of this document is to further the development of environmentally compatible and sustainable construction methods by providing comprehensive environmental information related to potential impacts in accordance with international standards.

No comparisons or benchmarking is included in this EPD. Environmental declarations from different programs based upon differing PCRs may not be comparable. Comparison of the environmental performance of construction works and construction products using EPD information shall be based on the product's use and impacts at the construction works level. In general, EPDs may not be used for comparability purposes when not considered in a construction works context. Given this PCR ensures products meet the same functional requirements, comparability is permissible provided the information given for such comparison is transparent and the limitations of comparability explained. When comparing EPDs created using this PCR, variations and deviations are possible. Example of variations: Different LCA software and background LCI datasets may lead to different results for upstream or downstream of the life cycle stages declared.

Impact Category [TRACI 2.1]	Unit	Double Pane Annealed - Total (A1-A3)	Double Pane Tempered – Total (A1-A3)	Triple Pane Annealed - Total (A1-A3)	Triple Pane Tempered - Total (A1-A3)
Global Warming Potential	[kg CO_2 eq.]	**39.6**	**54.3**	**59.0**	**93.9**
Ozon Depletion Potential	[kg CFC-11 eq.]	**5.19E-06**	**4.48E-06**	**9.02E-06**	**8.92E-06**
Acidification Potential	[kg SO_2 eq.]	**0.137**	**0.157**	**0.204**	**0.268**
Eutrophication Potential	[kg N eq.]	**0.00857**	**0.01012**	**0.01257**	**0.01703**
Photochemical Ozone Creation Potential	[kg O_3 eq.]	**3.35**	**3.80**	**4.85**	**6.50**
Mineral resource depletion potential	[kg Fe eq., per ReCiPe 1.08]	**3.211**	**2.758**	**6.37**	**5.70**
Resources, fossil fuels	[MJ]	**63.8**	**91.8**	**94.0**	**162**

Scope and Boundaries of the Life Cycle Assessment

The Life Cycle Assessment (LCA) was performed according to ISO 14040 (ISO, 2006) and ISO 14044 (ISO, 2006) following the requirements of the ASTM EPD Program Instructions and referenced PCR.

System Boundary: Cradle-to-gate

Allocation Method: No allocation required

Declared Unit: 1 m^2 (7.5 kg) of insulating glass

1 Organization, Product, and Product Category Descriptions

1.1 DESCRIPTION OF COMPANY/ORGANIZATION

Cardinal Glass Industries is a management-owned S-Corporation leading the industry in the development of residential glass for windows and doors. We have grown to more than 6,000 employees located at 43 manufacturing locations around the United States.

Cardinal operates (5) divisions:

- Cardinal FG (float glass)
- Cardinal CT (custom tempered glass)
- Cardinal LG (laminated glass)
- Cardinal CG (coated glass)
- Cardinal IG (insulating glass)

1.2 DESCRIPTION AND DEFINITION OF PRODUCTS

Multi-pane insulating glass units (IGU) are used to improve the energy efficiency of windows. Low-E coatings and argon gas fills can be used to further enhance the glazing performance. Tempered and/or laminated glass can be incorporated to address life safety glazing issues. Seal durability, both in material selection and manufacturing quality, is critical to the long term performance of the IGU.

1.3 PRODUCT USE AND APPLICATION

After fabrication into sealed insulating glass units, the final product is shipped to a customer for installation into a window system.

1.4 TECHNICAL REQUIREMENTS

Primary use is governed by building codes. These codes will layout safety glazing requirements, structural sufficiency needs, and building energy compliance.

1.5 MATERIAL CONTENT

The composition of processed glass products produced by Cardinal is given below in Table 1-1.

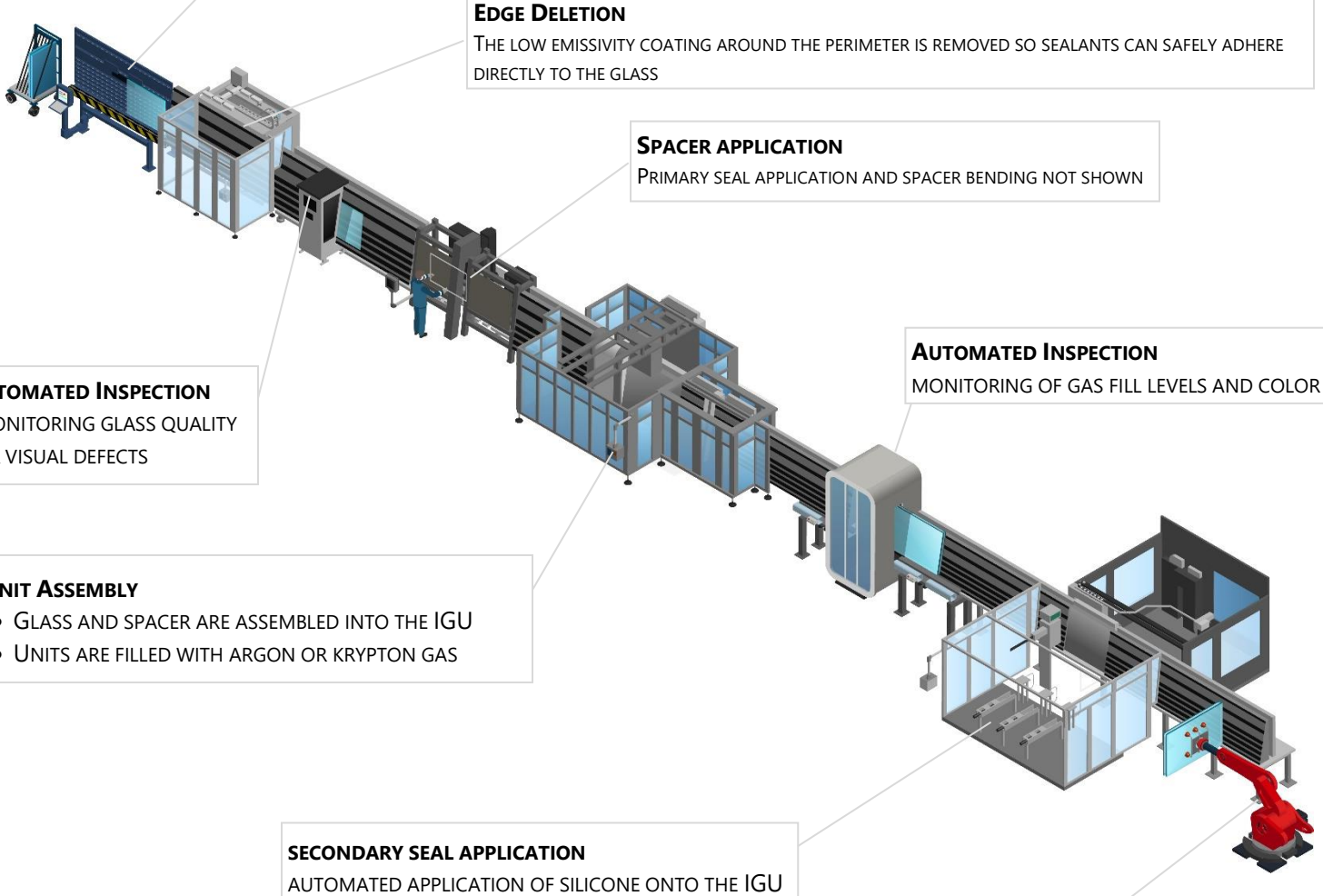
Table 1-1: Material composition of insulating glass

Material inputs	Mass %			
	Double, annealed	Double, tempered	Triple, annealed	Triple, tempered
Glass	44%	27%	45%	27%
Coated glass	49%	36%	48%	35%
Tempered glass	-	19%	-	17%
Coated tempered glass	-	12%	-	14%
Aluminum	0.3%	0.2%	0.3%	0.2%
Argon	1%	1%	2%	2%
Desiccant	1%	0.9%	2%	1%
Masking film	2%	2%	0.9%	1%
PIB	0.1%	0.1%	0.2%	0.1%
Silicone	0.7%	0.6%	0.9%	0.8%
Plastic spacer	0.03%	0.02%	0.04%	0.03%
Stainless steel	1%	1%	2%	1%

2 Life Cycle Stages

2.1 PRODUCTION

Cardinal insulating glass units are produced on a bespoke high speed automated production line. The units are produced in a made to order process, allowing for near infinite different combinations of glass, spacers, and options. At multiple points in the production process, the units are monitored for quality and integrity. They are shipped sequenced, in our customers production order, and in a just in time manner for our customers to install into their window and door assemblies.



GLASS LOADING
RAW GLASS IS LOADED ONTO THE PRODUCTION LINE

EDGE DELETION
THE LOW EMISSIVITY COATING AROUND THE PERIMETER IS REMOVED SO SEALANTS CAN SAFELY ADHERE DIRECTLY TO THE GLASS

SPACER APPLICATION
PRIMARY SEAL APPLICATION AND SPACER BENDING NOT SHOWN

AUTOMATED INSPECTION
MONITORING GLASS QUALITY FOR VISUAL DEFECTS

AUTOMATED INSPECTION
MONITORING OF GAS FILL LEVELS AND COLOR

UNIT ASSEMBLY
- GLASS AND SPACER ARE ASSEMBLED INTO THE IGU
- UNITS ARE FILLED WITH ARGON OR KRYPTON GAS

SECONDARY SEAL APPLICATION
AUTOMATED APPLICATION OF SILICONE ONTO THE IGU

UNLOADING AND PACKAGING
IGUS ARE SORTED AND SEQUENCED FOR SHIPMENT TO CUSTOMERS

The following life cycle stages are evaluated:

- **Material Extraction and Pre-Processing -** Raw material extraction, pre-processing, and upstream transport for raw substance manufacture, but excludes the inbound transport of materials to the manufacturing facility
- **Transport -** Inbound transport of raw materials from the supplier to the manufacturing facility
- **Manufacturing -** Includes the energy and inputs to manufacturing processed glass products

2.2 PACKAGING

The insulating glass product is packaged in cardboard and secured using plastic and steel banding as well as plastic wrap. The flat glass is also supported using wood.

3 Life Cycle Assessment Background Information

3.1 FUNCTIONAL UNIT

The declared unit for processed glass is 1 m^2 of glass. Each 1 m^2 double pane insulating glass weighs 15.6 kg, and each triple pane insulating glass weights 23.9 kg. Each pane is 3 mm thick.

3.2 SYSTEM BOUNDARY

The system boundary of the study is cradle-to-gate.

3.3 ESTIMATES AND ASSUMPTIONS

None.

3.4 CUT-OFF CRITERIA

No cut-off criteria had to be applied within this study. The system boundary was defned based on relevance to the goal of the study. For the processes within the system boundary, all available energy and material flow data have been included in the model. In cases where no matching LCI are available to represent a flow, proxy data have been applied based on conservative assumptions regarding environmental impacts.

3.5 BACKGROUND DATA

The LCA model was created using the GaBi ts software system v9.2 for life cycle engineering, developed by thinkstep AG. The GaBi 2019 LCI database provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

3.6 DATA QUALITY

A variety of tests and checks were performed throughout the project to ensure the high quality of the completed LCA. Data included first-hand company manufacturing data in combination with consistent background LCI information from the GaBi 2019 databases.

Primary data represent the production of processed glass at Cardinal facilities located in the United States. As such, the geographical coverage for this study is based on the respective system boundaries for all processes and products produced at each facility. Whenever geographically-relevant background data are not readily available, European or global data are to be used as proxies.

3.7 PERIOD UNDER REVIEW

The primary data collected from Cardinal are intended to represent production within the 2018 calendar year.

3.8 ALLOCATION

No allocation had to be applied.

3.9 COMPARABILITY

A comparison or evaluation of EPD data is only possible if all data sets to be compared are 1) created according to EN 15804 and 2) are considered in a whole building context or utilize identical defined use stage scenarios. Give this PCR is cradle to gate in scope, comparisons of EPD data from one product to another are not allowed. Refer to section 5.3 of EN 15804 for further information.

4 Life Cycle Assessment Results

Life cycle assessment results for insulating glass products covered in this EPD are presented per m^2 of glass products in this section. The cradle-to-gate impacts have been broken out into production of flat glass input, and processing.

4.1 DOUBLE PANE

Table 4-1: Resource use LCI results for double pane IGU glass products, per declared unit (1 m^2, 15.6 kg)

		Annealed			Tempered		
Flow	**Unit**	**Float Glass Only (A1)**	**Processing (A1-A3)**	**Total (A1-A3)**	**Float Glass only (A1)**	**Processing (A1-A3)**	**Total (A1-A3)**
Renewable primary energy as energy carrier	MJ	14.5	35.1	**14.5**	14.8	53.5	**68.3**
Renewable energy resources as material utilization	MJ	0.577	1.54	**0.577**	0.628	1.74	**2.37**
Renewable total primary energy demand	MJ	15.1	36.6	**15.1**	15.4	55.2	**70.7**
Non-renewable primary energy as energy carrier	MJ	371	196	**371**	391	410	**800**
Non-renewable energy resources as material utilization	MJ	0.252	1.16	**0.252**	0.266	1.41	**1.67**
Non-renewable total primary energy demand	MJ	371	197	**371**	391	411	**802**
Use of secondary material	kg	-	-	**-**	-	-	**-**
Renewable secondary fuels	MJ	-	-	**-**	-	-	**-**
Non-renewable secondary fuels	MJ	-	-	**-**	-	-	**-**
Recovered energy	MJ	-	-	**-**	-	-	**-**
Use of net fresh water resources	m^3	61.7	95.8	**158**	63.0	123	**186**

Table 4-2: Wastes and outputs LCI results for double pane IGU glass products, per declared unit (1 m^2, 15.6 kg)

		Annealed			Tempered		
Flow	**Unit**	**Float Glass Only (A1)**	**Processing (A1-A3)**	**Total (A1-A3)**	**Float Glass only (A1)**	**Processing (A1-A3)**	**Total (A1-A3)**
Hazardous waste disposed	kg	2.80E-07	1.66E-04	**1.66E-04**	2.94E-07	1.28E-04	**1.29E-04**
Non-hazardous waste disposed	kg	1.13	1.15	**2.28**	1.19	0.99	**2.18**
High-level radioactive waste	kg	0.00543	0.00744	**0.0129**	0.00582	0.0120	**0.0178**
Intermediate- and low-level radioactive waste	kg	1.85E-04	2.47E-04	**4.32E-04**	1.98E-04	4.04E-04	**6.03E-04**
Components for re-use	kg	-	-	**-**	-	-	**-**
Materials for recycling	kg	0.0500	0.000	**0.0500**	0.0490	0.000	**0.0490**
Materials for energy recovery	kg	-	-	**-**	-	-	**-**
Exported energy	MJ	-	-	**-**	-	-	**-**

Table 4-3: LCIA results for double pane IGU glass products, per declared unit (1 m^2, 15.6 kg)

Impact Category [TRACI 2.1]	Unit	Annealed			Tempered		
		Float Glass Only (A1)	Processing (A1-A3)	Total (A1-A3)	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Global Warming Potential	kg CO_2 eq.	26.5	13.1	**39.6**	27.9	26.4	**54.3**
Ozon Depletion Potential	kg CFC-11 eq.	-2.83E-12	5.19E-06	**5.19E-06**	-2.97E-12	4.48E-06	**4.48E-06**
Acidification Potential	kg SO_2 eq.	0.099	0.038	**0.137**	0.102	0.055	**0.157**
Eutrophication Potential	kg N eq.	0.00596	0.00261	**0.00857**	0.00614	0.00398	**0.01012**
Photochemical Ozone Creation Potential	kg O_3 eq.	2.82	0.54	**3.35**	2.87	0.92	**3.80**
Mineral Resource Depletion Potential	kg Fe eq., per ReCiPe 1.08	0.166	3.045	**3.211**	0.174	2.584	**2.758**
Resources, Fossil Fuels	MJ	48.3	15.6	**63.8**	50.7	41.1	**91.8**

4.2 TRIPLE PANE

Table 4-4: Resource use LCI results for triple pane IGU glass products, per declared unit (1 m^2, 23.9 kg)

Flow	Unit	Annealed			Tempered		
		Float Glass Only (A1)	Processing (A1-A3)	Total (A1-A3)	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Renewable primary energy as energy carrier	MJ	21.4	65.8	**87.2**	23.6	100.1	**124**
Renewable energy resources as material utilization	MJ	0.795	1.73	**2.52**	0.928	2.07	**2.99**
Renewable total primary energy demand	MJ	22.2	67.5	**89.7**	24.5	102	**127**
Non-renewable primary energy as energy carrier	MJ	539	309	**848**	619	774	**1392**
Non-renewable energy resources as material utilization	MJ	0.338	2.20	**2.54**	0.417	2.23	**2.64**
Non-renewable total primary energy demand	MJ	539	311	**850**	619	776	**1395**
Use of secondary material	kg	-	-	**-**	-	-	**-**
Renewable secondary fuels	MJ	-	-	**-**	-	-	**-**
Non-renewable secondary fuels	MJ	-	-	**-**	-	-	**-**
Recovered energy	MJ	-	-	**-**	-	-	**-**
Use of net fresh water resources	m^3	94.5	210.1	**304.7**	101.7	251.2	**352.9**

Table 4-5: Wastes and outputs LCI results for triple pane IGU glass products, per declared unit (1 m^2, 23.9 kg)

Flow	Unit	Annealed			Tempered		
		Float Glass Only (A1)	Processing (A1-A3)	Total (A1-A3)	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Hazardous waste disposed	kg	4.19E-07	3.36E-04	**3.36E-04**	4.70E-07	2.77E-04	**2.78E-04**
Non-hazardous waste disposed	kg	1.62	1.96	**3.57**	1.88	2.24	**4.12**
High-level radioactive waste	kg	0.00818	0.0152	**0.0234**	0.0093	0.0210	**0.0303**
Intermediate- and low-level radioactive waste	kg	2.78E-04	5.08E-04	**7.86E-04**	3.17E-04	7.06E-04	**1.02E-03**
Components for re-use	kg	-	-	**-**	-	-	**-**
Materials for recycling	kg	0.0810	0.000	**0.0810**	0.0834	0.000	**0.0834**
Materials for energy recovery	kg	-	-	**-**	-	-	-
Exported energy	MJ	-	-	**-**	-	-	**-**

Table 4-6: LCIA results for triple pane IGU glass products, per declared unit (1 m^2, 23.9 kg)

Impact Category [TRACI 2.1]	Unit	Annealed			Tempered		
		Float Glass Only (A1)	Processing (A1-A3)	Total (A1-A3)	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Global Warming Potential	kg CO_2 eq.	38.3	20.7	**59.0**	44.1	49.8	**93.9**
Ozon Depletion Potential	kg CFC-11 eq.	-4.13E-12	9.02E-06	**9.02E-06**	-4.72E-12	8.92E-06	**8.92E-06**
Acidification Potential	kg SO_2 eq.	0.137	0.0665	**0.204**	0.166	0.1021	**0.268**
Eutrophication Potential	kg N eq.	0.00828	0.00429	**0.01257**	0.01003	0.00700	**0.01703**
Photochemical Ozone Creation Potential	kg O_3 eq.	3.89	0.96	**4.85**	4.74	1.76	**6.50**
Mineral Resource Depletion Potential	kg Fe eq., per ReCiPe 1.08	0.240	6.130	**6.37**	0.276	5.425	**5.70**
Resources, Fossil Fuels	MJ	70.3	23.7	**94.0**	80.4	81.3	**162**

5 LCA Interpretation

The analysis results represent the cradle-to-gate environmental performance of insulating glass products. Detailed results are presented for only a select few impact categories, chosen because of their familiarity within the LCA community (Acidification Potential (AP), Eutrophication Potential (EP), Global Warming Potential (GWP), and Smog Formation Potential (SFP)).

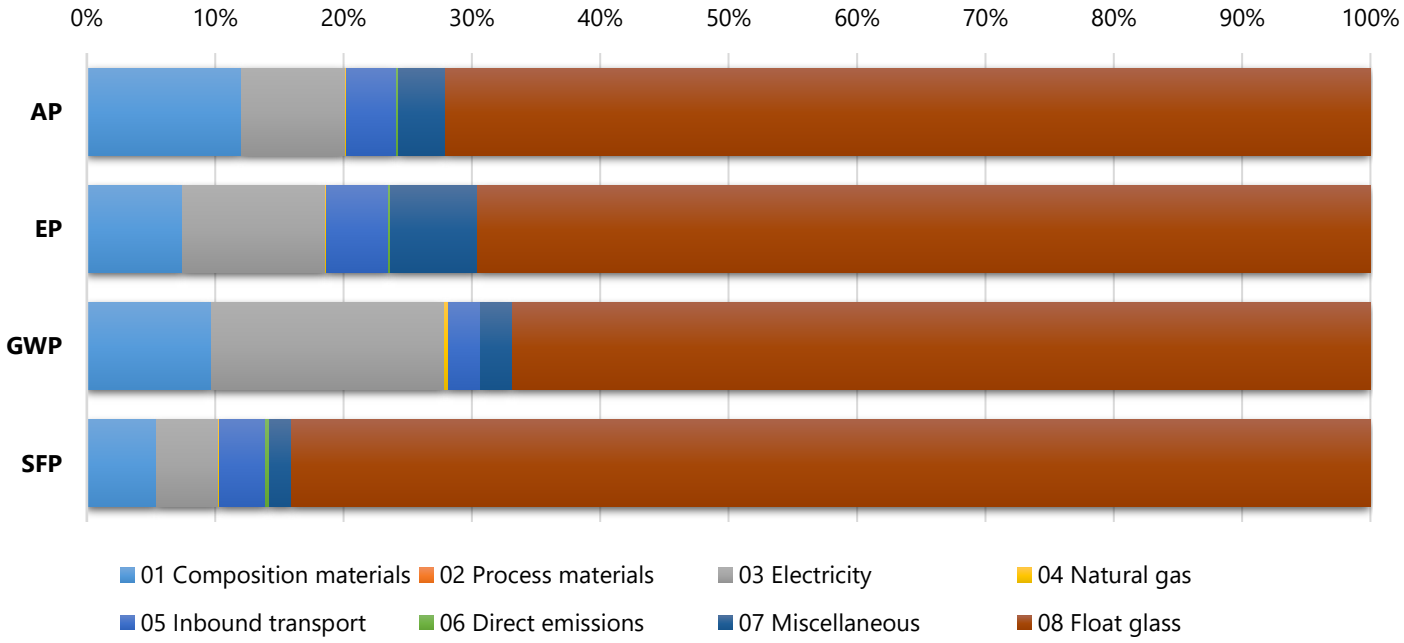


Figure 5-1: Relative contributions of uncoated glass production and the insulating process (including coating) to double pane annealed IGUs (TRACI 2.1)

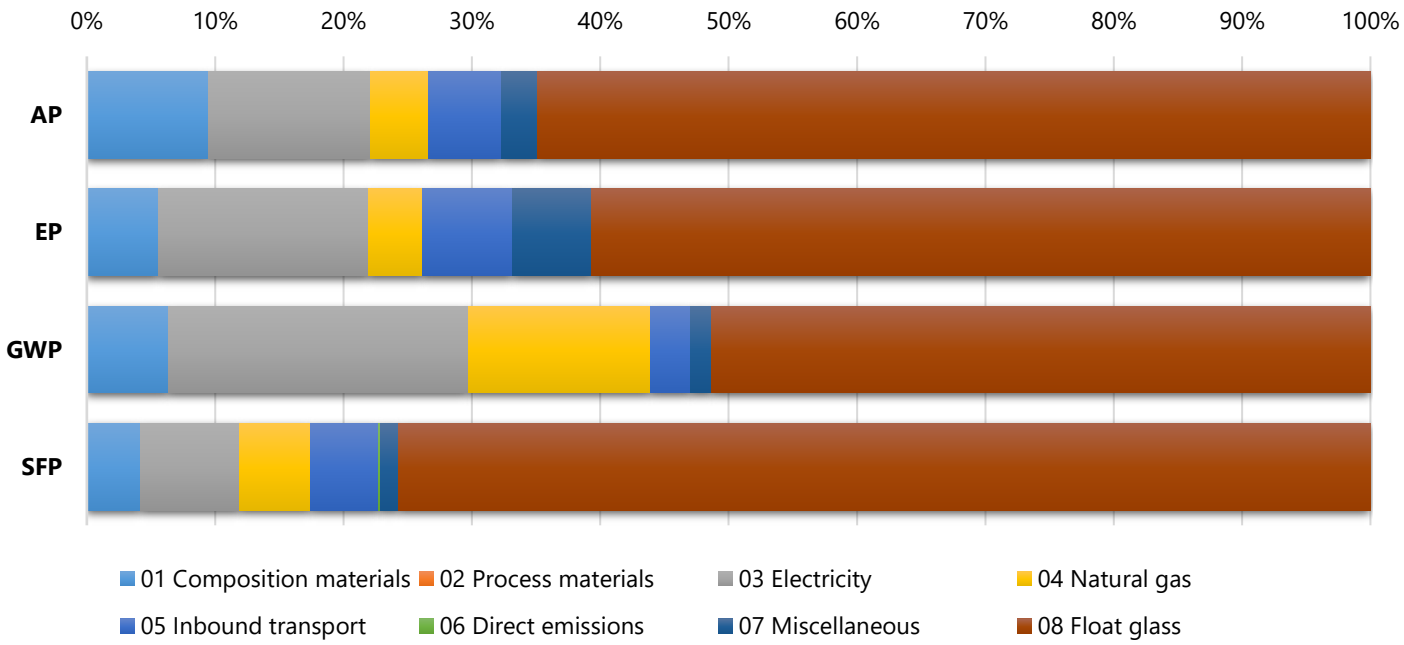


Figure 5-2: Relative contributions of uncoated glass production and the insulating process (including coating and tempering) to double pane tempered IGUs (TRACI 2.1)

Figure 5-1 and Figure 5-2 present the double pane results for annealed and tempered, respectively. Composition materials include the spacers, silicon, and other components of IGU production. As with all other products, uncoated glass is the primary driver of results. Within the insulating process itself, the difference between annealed and tempered is the natural gas used in tempering, as well as additional electricity where sites use electric furnaces. Electricity used for just the insulating process, however, is also a large contributor to results.

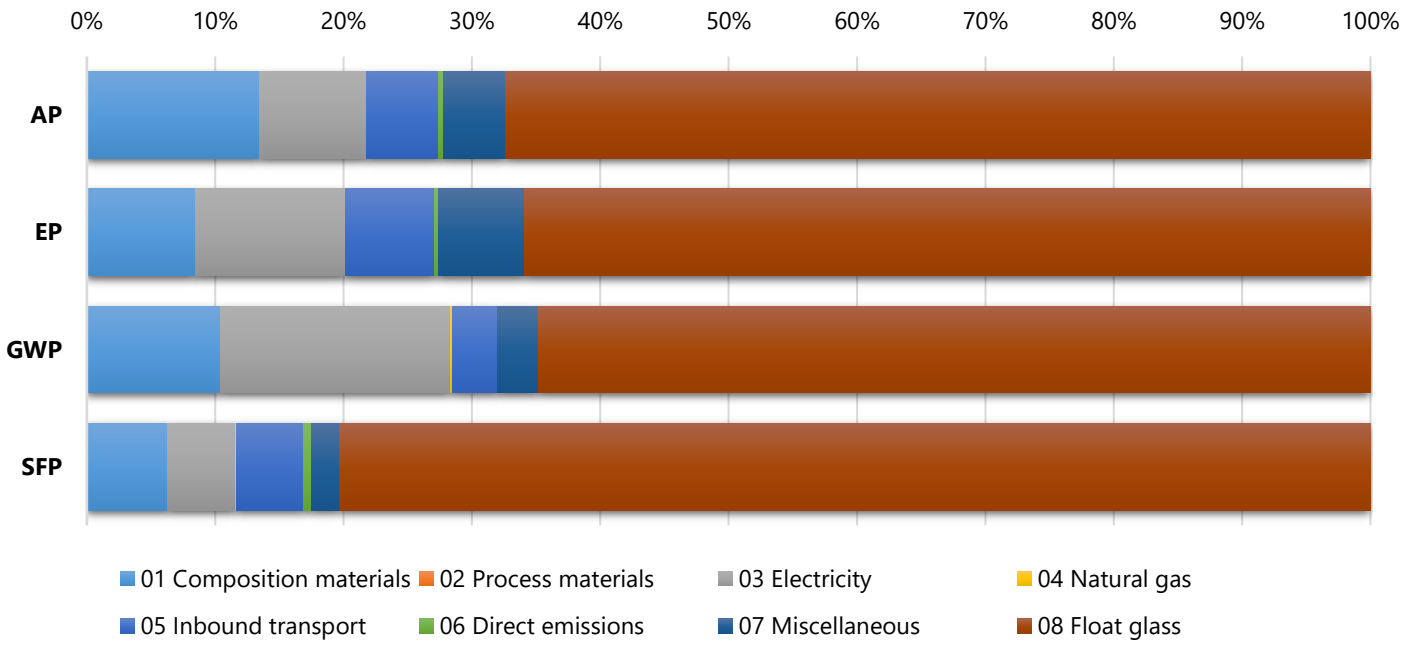


Figure 5-3: Relative contributions of uncoated glass production and the insulating process (including coating) to triple pane annealed IGUs (TRACI 2.1)

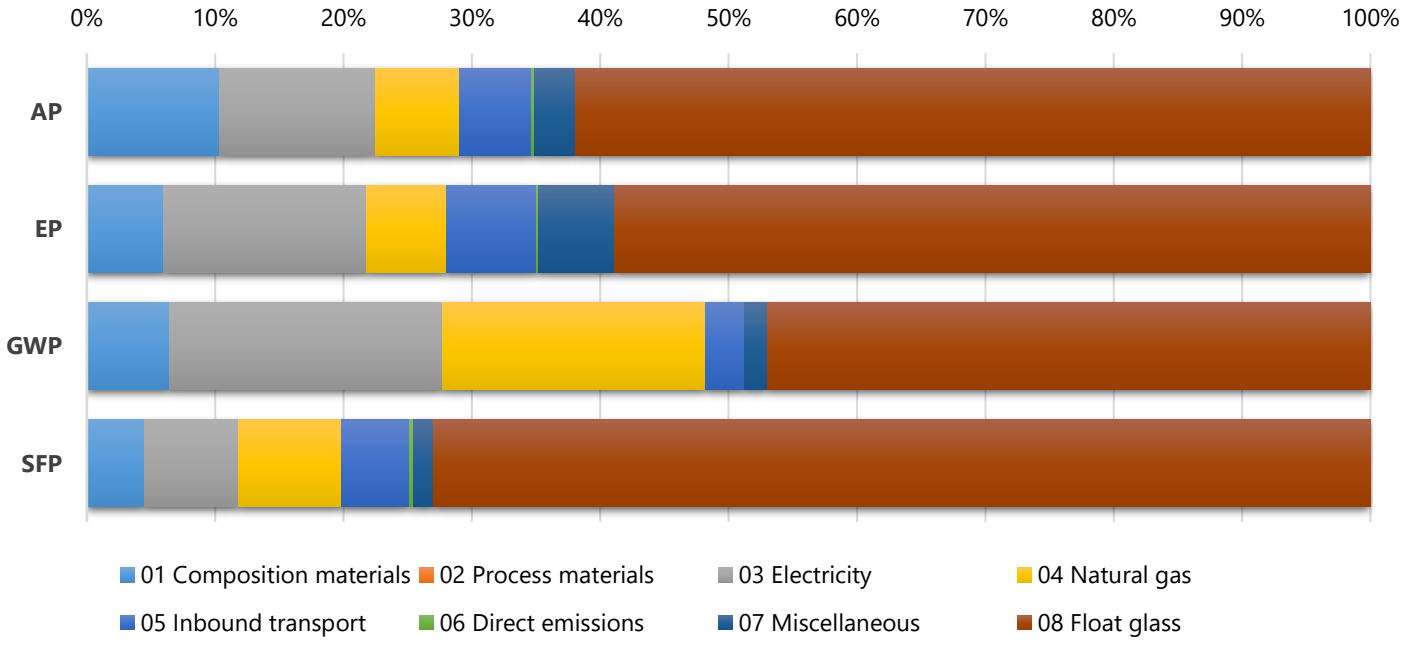


Figure 5-4: Relative contributions of uncoated glass production and the insulating process (including coating and tempering) to triple pane tempered IGUs (TRACI 2.1)

Figure 5-3 and Figure 5-4 present the triple pane results for annealed and tempered, respectively. The results follow similar trends as the double pane IGUs, but the insulating process contributes to a larger fraction of the toal impact, as compared to the double pane.

6 Additional Environmental Information

6.1 ENVIRONMENT AND HEALTH DURING MANUFACTURING

Please refer to the Article Data Sheet for flat glass products, which can be found at www.cardinalcorp.com.

6.2 ENVIRONMENT AND HEALTH DURING USE

Please refer to the Article Data Sheet for flat glass products, which can be found at www.cardinalcorp.com.

6.3 EXTRAORDINARY EFFECTS

Fire / Water / Mechanical Destruction

Please refer to the Article Data Sheet for flat glass products, which can be found at www.cardinalcorp.com.

6.4 ENVIRONMENTAL ACTIVITIES AND CERTIFICATIONS

Please refer to the Article Data Sheet for flat glass products, which can be found at www.cardinalcorp.com.

7 References

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