Environmental Product Declaration

According to ISO 14025

Processed 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: Processed Glass

Product Definition: Coated, tempered, and coated & tempered glass

Cardinal Coated Glass Products	LoĒ-180®	LoĒ²-272®	LoĒ²-240®	LoĒ-x89®
	LoĒ-180ESC®	LoĒ³-366®	LoĒ³-340®	Neat+®
	LoĒ²-270®	Quad LoĒ-452+®	LoĒ-i89®	

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

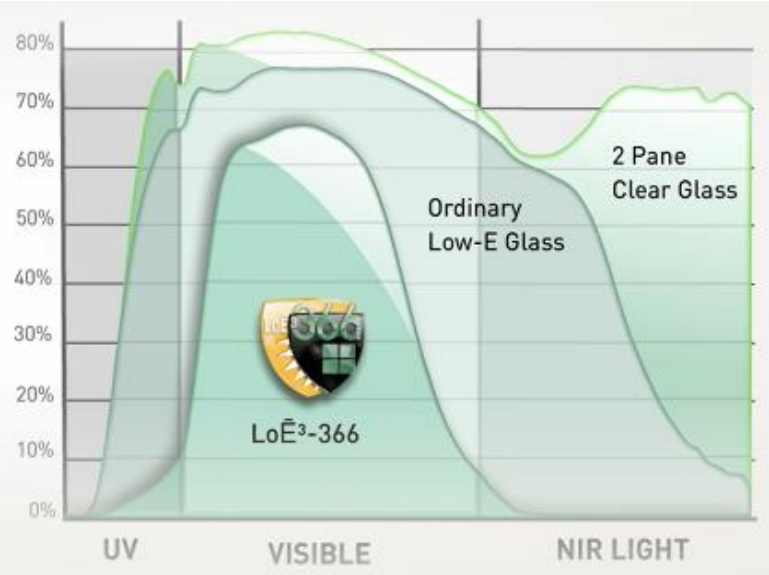
PCR Review was conducted by:

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

PRODUCT APPLICATION AND / OR CHARACTERISTICS

Coated glass, and in particular low-E coated glass, is used to enhance glazing energy performance.

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	Unit per m^2 of processed glass	Coated (Total, A1-A3)	Tempered (Total, A1-A3)	Coated & tempered (Total, A1-A3)
TRACI 2.1				
GWP	kg CO_2 eq.	13.7	17.1	**22.3**
AP	kg SO_2 eq.	0.0476	0.0479	**0.0641**
EP	kg N eq.	0.00295	0.00312	**4.21E-03**
POCP	kg O_3 eq.	1.25	1.31	**1.63**
ADPe	kg Fe eq., per ReCiPe 1.08	0.265	0.110	**0.361**
ADPf	MJ, surplus	22.8	31.5	**38.7**

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 processed 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

Low emissivity (Low-E) coated glass improves the energy efficiency of the window by rejecting ultraviolet and near infrared energy, while allowing visible light from the sun to pass through. It also reflects room temperature radiation to reduce heat transfer providing lower Ufactors.

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 presented in Table 1-1.

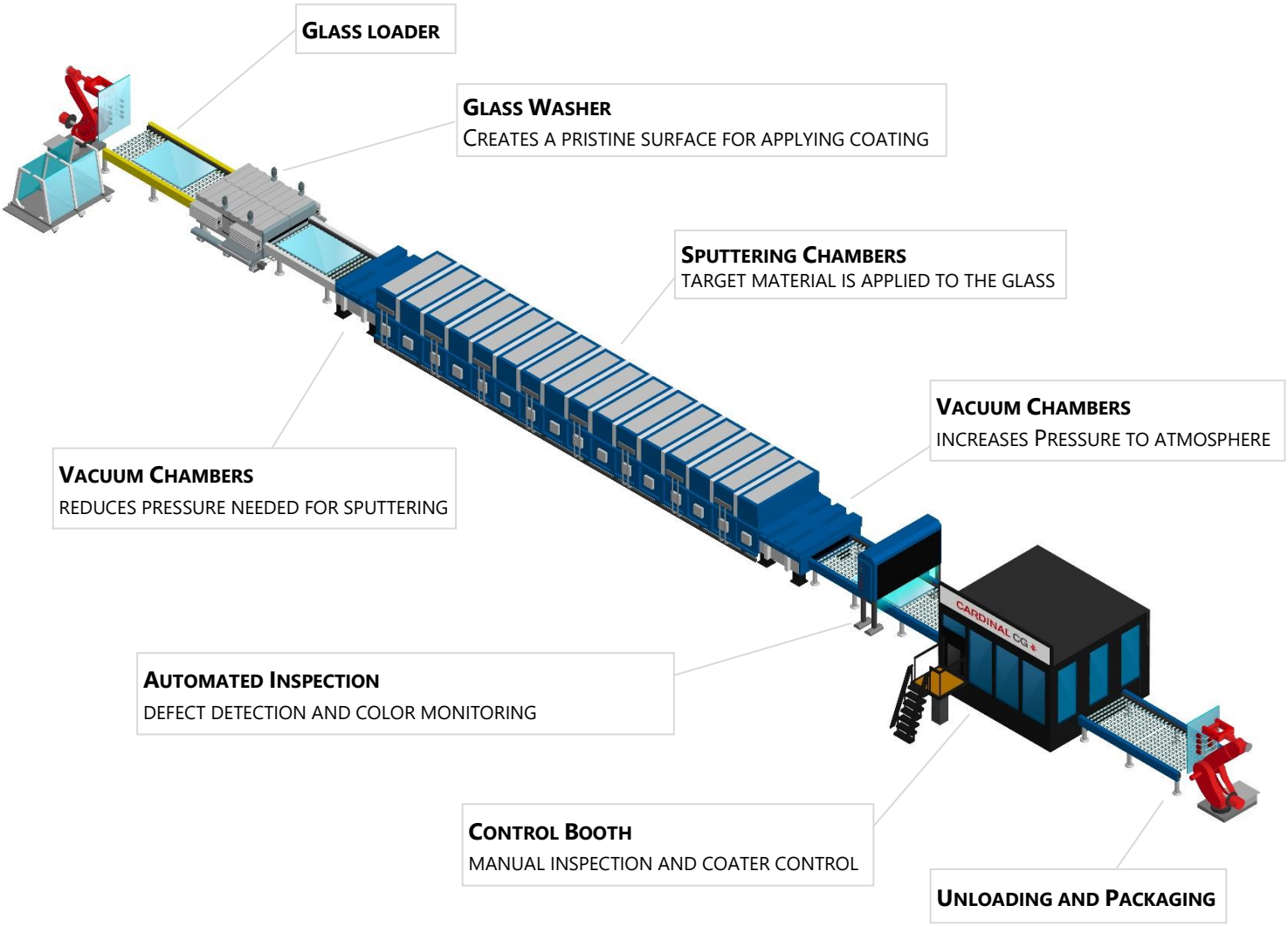
Table 1-1. Processed glass material content

Material inputs	Mass %		
	Coated	Tempered	Coated & Tempered
Glass oxide	99.95%	100.00%	99.95%
Nickel	<0.01%	-	<0.01%
Silicon	<0.01%	-	<0.01%
Silver	<0.01%	-	<0.01%
Tin	<0.01%	-	<0.01%
Titanium	<0.01%	-	<0.01%
Zinc	0.04%	-	0.04%

2 LIFE CYCLE STAGES

2.1 PRODUCTION

Energy efficient Low-E coatings consist of optically transparent nanoscopic layers sputtered onto glass via magnetron sputtering. The layers are deposited onto the glass substrate in sputtering chambers which are under vacuum. A high voltage magnetron ignites a plasma creating energetic ions of inert gases. The energetic ions forcefully collide with the target ejecting target atoms which deposit onto the glass substrate. The coated glass is then packaged and sent to customers to be processed into insulating glass units.



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 processed glass product is packaged in cardboard and secured using plastic and steel banding as well as plastic wrap. The processed 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 pane weighs 7.5 kg, assuming a glass density of 2,500 kg/m^3 and thickness of 3 mm.

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 flat and 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 the three types of processed glass 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 (coating and/or tempering).

4.1 COATED GLASS

Table 4-1: Resource use LCI results for coated glass products, per declared unit [1 m^2, 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Renewable primary energy as energy carrier	MJ	5.93	7.54	**13.5**
Renewable energy resources as material utilization	MJ	0.240	0.174	**0.414**
Renewable total primary energy demand	MJ	6.17	7.72	**13.9**
Non-renewable primary energy as energy carrier	MJ	150	35.3	**185**
Non-renewable energy resources as material utilization	MJ	0.099	0.326	**0.424**
Non-renewable total primary energy demand	MJ	150	35.7	**186**
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	25.6	18.4	**44.0**

Table 4-2: Wastes and outputs LCI results for coated glass products, per declared unit [1 m^2, 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Hazardous waste disposed	kg	1.13E-07	5.38E-08	**1.67E-07**
Non-hazardous waste disposed	kg	0.455	0.0207	**0.476**
High-level radioactive waste	kg	0.00213	0.00134	**0.00347**
Intermediate- and low-level radioactive waste	kg	7.24E-05	4.57E-05	**1.18E-04**
Components for re-use	kg	-	-	**-**
Materials for recycling	kg	0.0221	-	**0.0221**
Materials for energy recovery	kg	-	-	**-**
Exported energy	MJ	-	-	**-**

Table 4-3: LCIA results for coated glass products per functional unit [1 m^2, 7.5 kg]

Impact Category [TRACI 2.1]	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Global Warming Potential	kg CO_2 eq.	11.1	2.67	**13.7**

Impact Category [TRACI 2.1]	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Ozone Depletion Potential[1]	kg CFC-11 eq.	-	-	**-**
Acidification Potential	kg SO_2 eq.	0.0409	0.00669	**0.0476**
Eutrophication Potential	kg N eq.	0.00246	4.95E-04	**0.00295**
Photochemical Ozone Creation Potential	kg O_3 eq.	1.16	0.0846	**1.25**
Metal Depletion	kg Fe eq., per ReCiPe 1.08	0.0694	0.195	**0.265**
Resources, Fossil Fuels	MJ	20.2	2.56	**22.8**

4.2 TEMPERED GLASS

Table 4-4: Energy usage LCI results for tempered glass products, per declared unit [1 m^2, 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Renewable primary energy as energy carrier	MJ	5.41	6.81	**12.2**
Renewable energy resources as material utilization	MJ	0.233	0.195	**0.428**
Renewable total primary energy demand	MJ	5.64	7.00	**12.6**
Non-renewable primary energy as energy carrier	MJ	156	103.2	**259**
Non-renewable energy resources as material utilization	MJ	0.107	0.291	**0.399**
Non-renewable total primary energy demand	MJ	156	103.5	**259**
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	23.6	15.4	**38.9**

Table 4-5: Wastes and outputs LCI results for tempered glass products, per declared unit [1 m^2, 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Hazardous waste disposed	kg	1.19E-07	8.71E-08	**2.06E-07**
Non-hazardous waste disposed	kg	0.472	0.0283	**0.500**
High-level radioactive waste	kg	0.00255	0.00209	**0.00464**
Intermediate- and low-level radioactive waste	kg	8.68E-05	7.13E-05	**1.58E-04**
Components for re-use	kg	-	-	**-**
Materials for recycling	kg	0.0171	-	**0.0171**
Materials for energy recovery	kg	-	-	**-**
Exported energy	MJ	-	-	**-**

Table 4-6: LCIA results for tempered glass products per functional unit [1 m^2, 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Global Warming Potential	kg CO_2 eq.	11.1	6.91	**17.1**
Ozon Depletion Potential[2]	kg CFC-11 eq.	-	-	**-**
Acidification Potential	kg SO_2 eq.	0.0407	0.0092	**0.0479**
Eutrophication Potential	kg N eq.	0.00247	7.92E-04	**0.00312**
Photochemical Ozone Creation Potential	kg O_3 eq.	1.15	0.21	**1.31**
Metal Depletion	kg Fe eq., per	0.069	0.0470	**0.110**

[1] ODP values were originally in the order of magnitude of negative 10^{-12}. The negative values are a result of credits given in the background systems of various GaBi datasets. Since the magnitude of these ODP results is extremely low, the values are read and interpreted as zero.

[2] ODP values were originally in the order of magnitude of negative 10^{-12}. The negative values are a result of credits given in the background systems of various GaBi datasets. Since the magnitude of these ODP results is extremely low, the values are read and interpreted as zero.

	ReCiPe 1.08			
Resources, fossil fuels	MJ	20.1	13.1	**31.5**

4.3 COATED AND TEMPERED GLASS

Table 4-7: Resource use LCI results for coated tempered glass products, per declared unit [1 m^2, 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Renewable primary energy as energy carrier	MJ	6.46	19.7	**26.1**
Renewable energy resources as material utilization	MJ	0.272	0.492	**0.763**
Renewable total primary energy demand	MJ	6.73	20.2	**26.9**
Non-renewable primary energy as energy carrier	MJ	177	147.5	**324**
Non-renewable energy resources as material utilization	MJ	0.120	0.822	**0.942**
Non-renewable total primary energy demand	MJ	177	148	**325**
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	28.1	37.8	**65.9**

Table 4-8: Wastes and outputs LCI results for coated tempered glass products, per declared unit [1 m^2, 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Hazardous waste disposed	kg	1.35E-07	1.65E-07	**2.99E-07**
Non-hazardous waste disposed	kg	0.537	0.0577	**0.594**
High-level radioactive waste	kg	0.00275	0.00361	**0.00637**
Intermediate- and low-level radioactive waste	kg	9.38E-05	1.23E-04	**2.17E-04**
Components for re-use	kg	-	-	**-**
Materials for recycling	kg	0.0219	-	**0.0219**
Materials for energy recovery	kg	-	-	**-**
Exported energy	MJ	-	-	**-**

Table 4-9: LCIA results for coated tempered glass products per declared unit [1 m^2, 7.5 kg]

Impact Category [TRACI 2.1]	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Global Warming Potential	kg CO_2 eq.	12.6	9.67	**22.3**
Ozon Depletion Potential[3]	kg CFC-11 eq.	-	-	**-**
Acidification Potential	kg SO_2 eq.	0.0463	0.0177	**0.0641**
Eutrophication Potential	kg N eq.	2.80E-03	1.41E-03	**4.21E-03**
Photochemical Ozone Creation Potential	kg O_3 eq.	1.31	0.315	**1.63**
Metal Depletion	kg Fe eq., per ReCiPe 1.08	0.0788	0.282	**0.361**
Resources, Fossil Fuels	MJ	22.9	15.8	**38.7**

5 LCA INTERPRETATION

The analysis results represent the cradle-to-gate environmental performance of processed glass products.

Detailed results are presented for only a select few impact categories, chosen because of their familiarity within the LCA

[3] ODP values were originally in the order of magnitude of negative 10^{-12}. The negative values are a result of credits given in the background systems of various GaBi datasets. Since the magnitude of these ODP results is extremely low, the values are read and interpreted as zero.

community (Acidification Potential (AP), Eutrophication Potential (EP), Global Warming Potential (GWP), and Smog Formation Potential (SFP)).

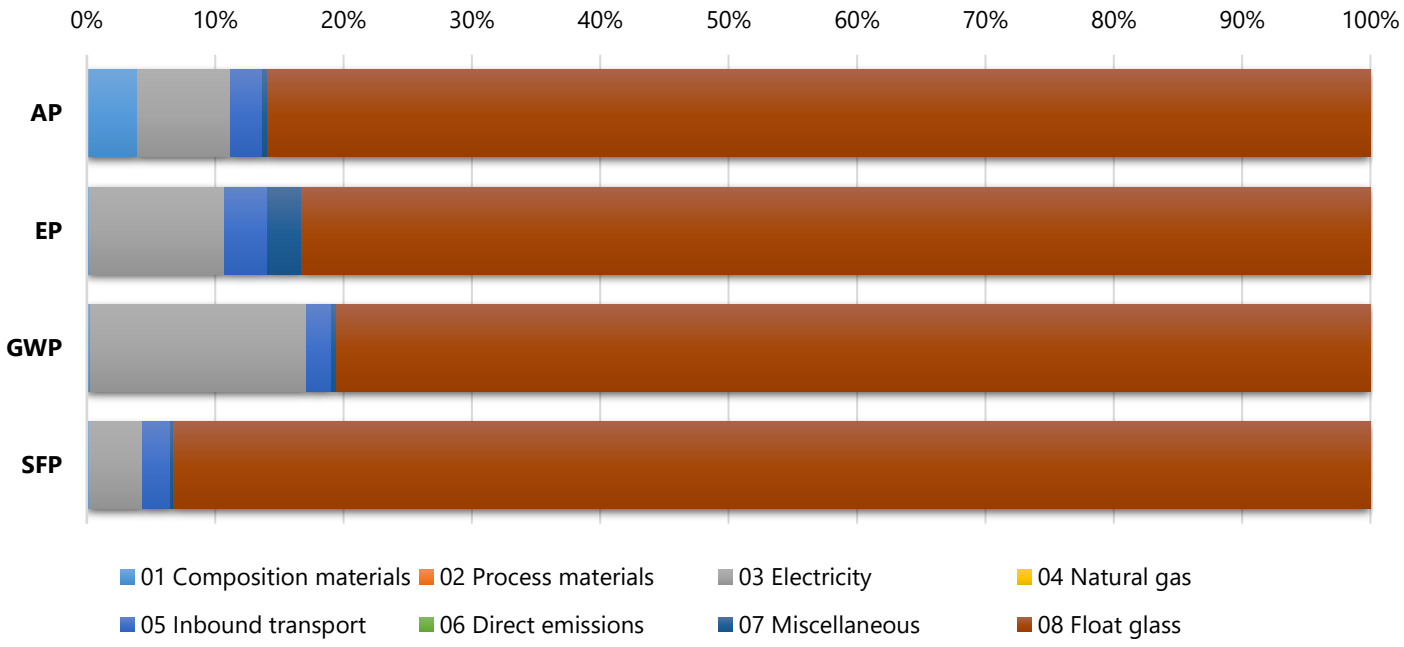


Figure 5-1: Relative contributions of flat glass production and the coating process (TRACI 2.1)

Relative contributions of coated glass manufacturing are broken down in Figure 5-1. The potential impacts of uncoated glass significantly outweigh those of glass coating. The largest category driving the potential impacts of the coating process is the electricity input.

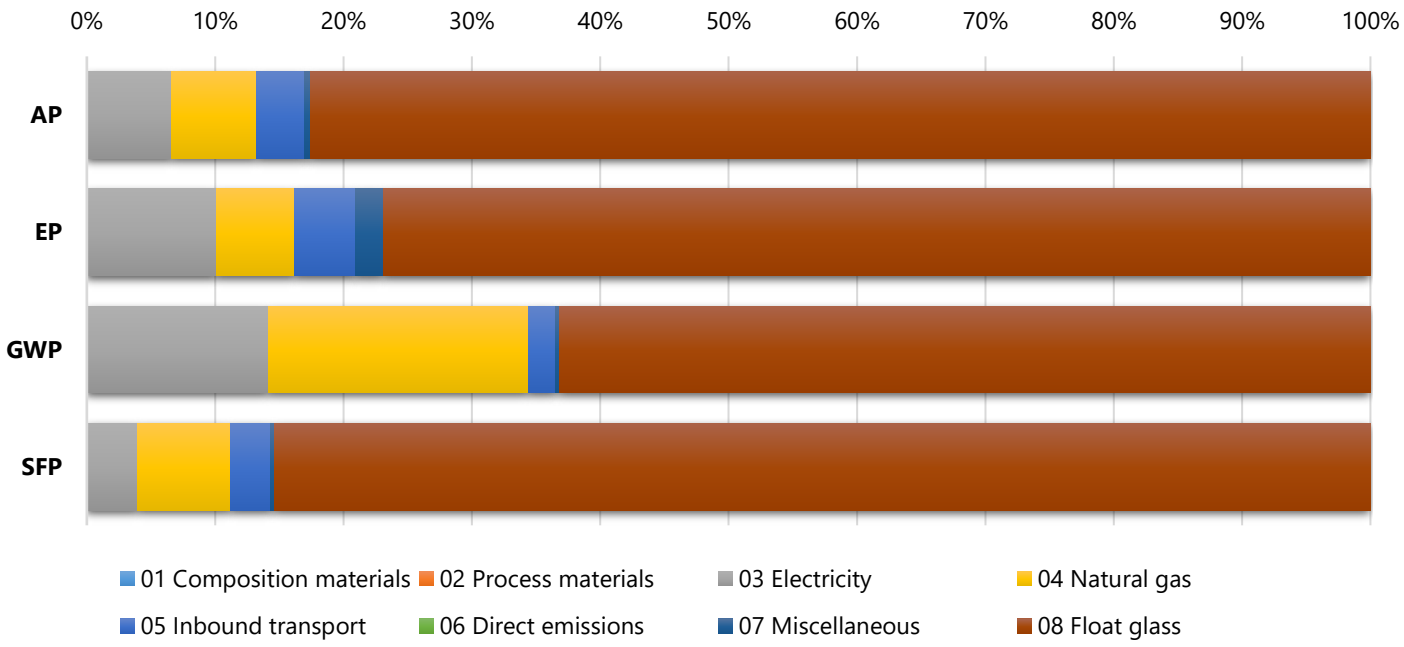


Figure 5-2: Relative contributions of uncoated glass production and tempering (TRACI 2.1)

Relative contributions of tempered glass manufacturing are broken down in Figure 5-2. Compared to coating, tempering has a much higher contribution to the total, though the impacts of uncoated glass are still the most significant. The largest drivers within tempering are the energy inputs – electricity and natural gas.

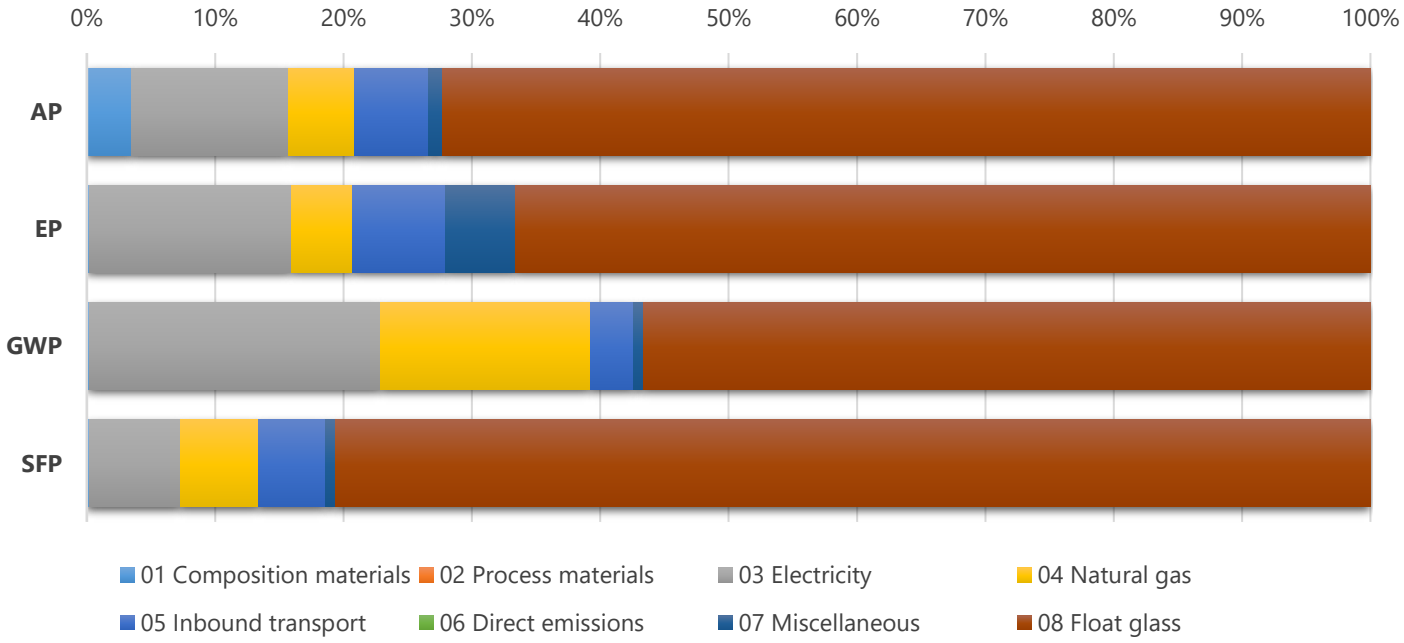


Figure 5-3: Relative contributions of uncoated glass production and coating and tempering combined processes (TRACI 2.1)

Relative contributions of tempered and coated glass manufacturing are broken down in Figure 5-3. Note that coated and tempered products are not necessarily the sum of the two processes, as each of these three products are calculated as a production weighted average of the various facilities. Differences between facilities and their corresponding production

volumes does not allow for a linear relationship.

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

Bare, J. (2012). *Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) - Software Name and Version Number: TRACI version 2.1 - User's Manual.* Washington, D.C.: U.S. EPA.

EPA. (2012). *Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) - User's Manual.* Washington, D.C.: US EPA.

IBU/UL Environment. (2014). *PCR for Building-Related Products and Services - Part A: Calculation Rules for the LCA and Requirements Project Report. (V1.3, 06.19.2014).*

ISO. (2006). *ISO 14025: Environmental labels and declarations - Type III environmental declarations - Principles and procedures.* Geneva: International Organization for Standardization.

ISO. (2006). *ISO 14040: Environmental management - Life cycle assessment - Requirements and guidelines.* Geneva: International Organization for Standardization.

ISO. (2006). *ISO 14044: Environmental management - Life cycle assessment - Principles and framework.* Geneva: International Organization for Standardization.

ISO. (2007). *ISO 21930: Sustainability in buildings and civil engineering works -- Core rules for environmental product declarations of construction products and services.* Geneva: International Organization for Standardization.

Sphera. (2019). *GaBi LCA Database Documentation*. Retrieved from Sphera: http://database-documentation.gabi-software.com

UL Environment. (2016). *PCR Guidance for Building-Related Products and Services - Part B: Processed Glass EPD Requirements.* US.

CONTACT INFORMATION

STUDY COMMISSIONER

Cardinal Glass Industries
775 Prairie Center Drive, Suite 200
Eden Prairie, MN 55433
+1 952-935-1722
www.cardinalcorp.com

LCA PRACTITIONER

Sphera Solutions, Inc.
170 Milk St. 3rd floor
Boston, MA 02109
+1 617-247-4477
www.sphera.com