Environmental Product Declaration

According to ISO 14025

Flat Glass

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.

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: Flat Glass

Product Definition: Untreated and uncoated flat glass

Declaration Type: Business to business

PCR Reference:

- GANA PCR for Flat Glass: UN CPC 3711 (NSF International, October 1, 2019)

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

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	Uncoated: Raw Materials	Uncoated: Production	Total
Global Warming Potential	kg CO_2 eq.	421	945	**1,370**
Acidification Potential	kg SO_2 eq.	0.861	4.09	**4.95**
Eutrophication Potential	kg N eq.	0.0479	0.25	**0.298**
Photochemical Ozone Creation Potential	kg O_3 eq.	17.7	122	**139**
Mineral Resource Depletion Potential	kg Fe eq., per ReCiPe 1.08	2.82	5.72	**8.54**

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 metric tonne (1000 kg) of flat glass, maintained for a 30-year period

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

Float glass is the process used to make flat glass. From there the glass can be tempered or laminated for safety glazing requirements, low-E coated for energy efficiency, and then fabricated into multi-pane insulating glass units for installation into a window.

1.3 PRODUCT USE AND APPLICATION

Flat glass may be used within the building envelope or interior, or further processed into tempered, laminated, and/or multi-pane insulating glass units.

1.4 TECHNICAL REQUIREMENTS

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

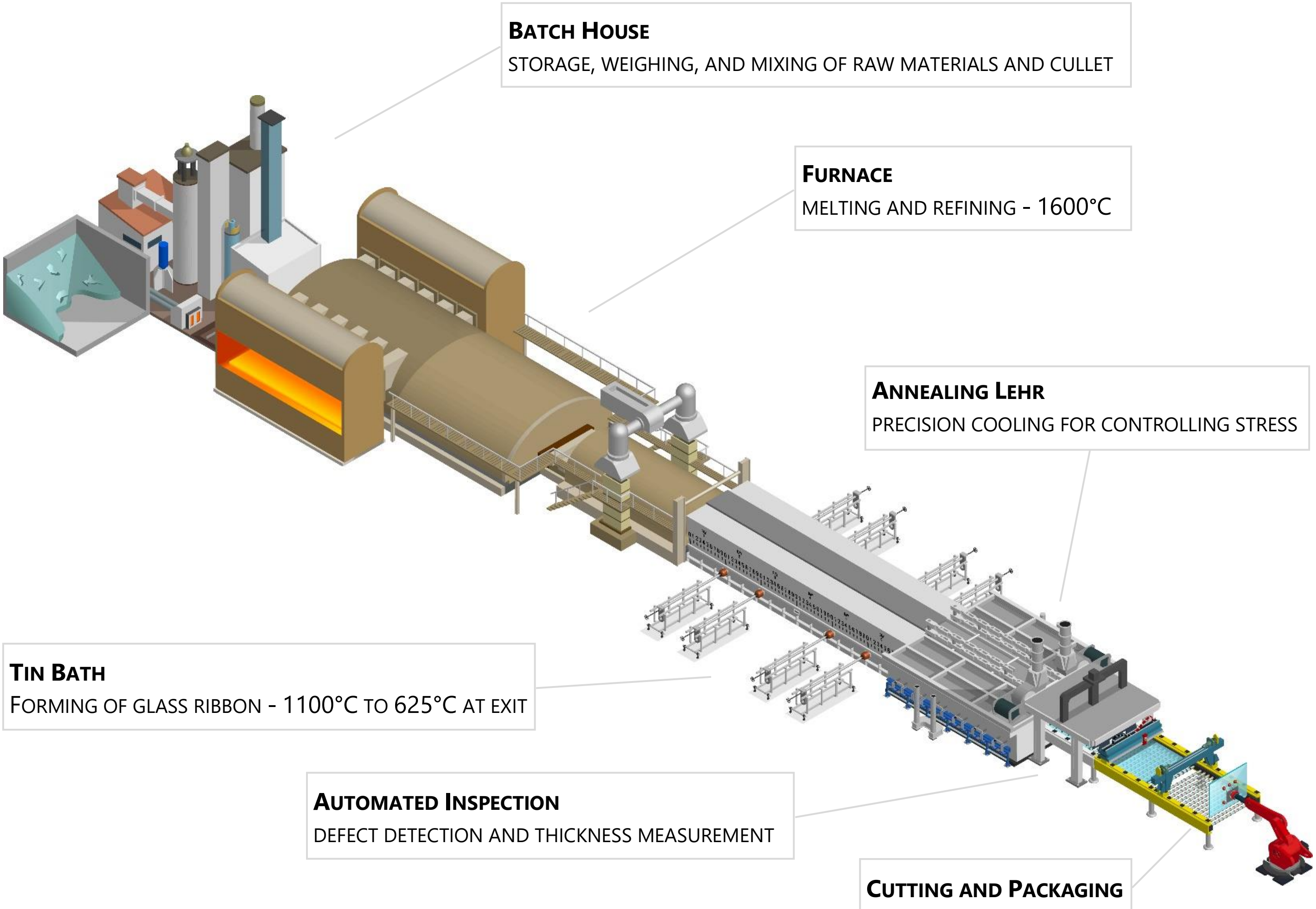
1.5 MATERIAL CONTENT

The composition of the final uncoated flat glass produced by Cardinal is 100% glass oxide (CAS number: 65997-17-3).

2 LIFE CYCLE STAGES

2.1 PRODUCTION

To manufacture float glass, raw materials (sand, soda ash, limestone, dolomite, cullet, etc.) are stored, weighed, and mixed in a batch process inside of the batch house. This batch material is conveyed to the furnace where it is melted to form molten glass. After melting and refining in the furnace, the glass pours onto molten tin inside of the tin bath. Glass has a lower density than that of tin, allowing the glass to float and achieve a smooth, flat surface. It is in the tin bath that the glass is stretched both laterally and longitudinally to create a continuous ribbon of the desired thickness and width. Upon leaving the tin bath, the ribbon passes through the annealing lehr where it is cooled slowly, at a rate that prevents excessive permanent stress formation in the glass. Once through the permanent stress zones of the lehr, the continuous glass ribbon is cooled to a temperature at which it can be scored by automatic cutters, separated, and have the edge trim removed. Finished glass is then packed and shipped to customers for further processing.



The following life cycle stages are evaluated:

- **Material Extraction and Pre-Processing -** Raw material extraction and processing, along with inbound transport of materials to glass production facility
- **Production -** Manufacture of flat glass from primary materials as well as materials used in packaging. This stage ends when the final glass product leaves the production line and is stored onsite.
- **Packaging and Storage -** This stage includes the onsite storage of glass product before it leaves the facility to be delivered to the end user or fabricator.

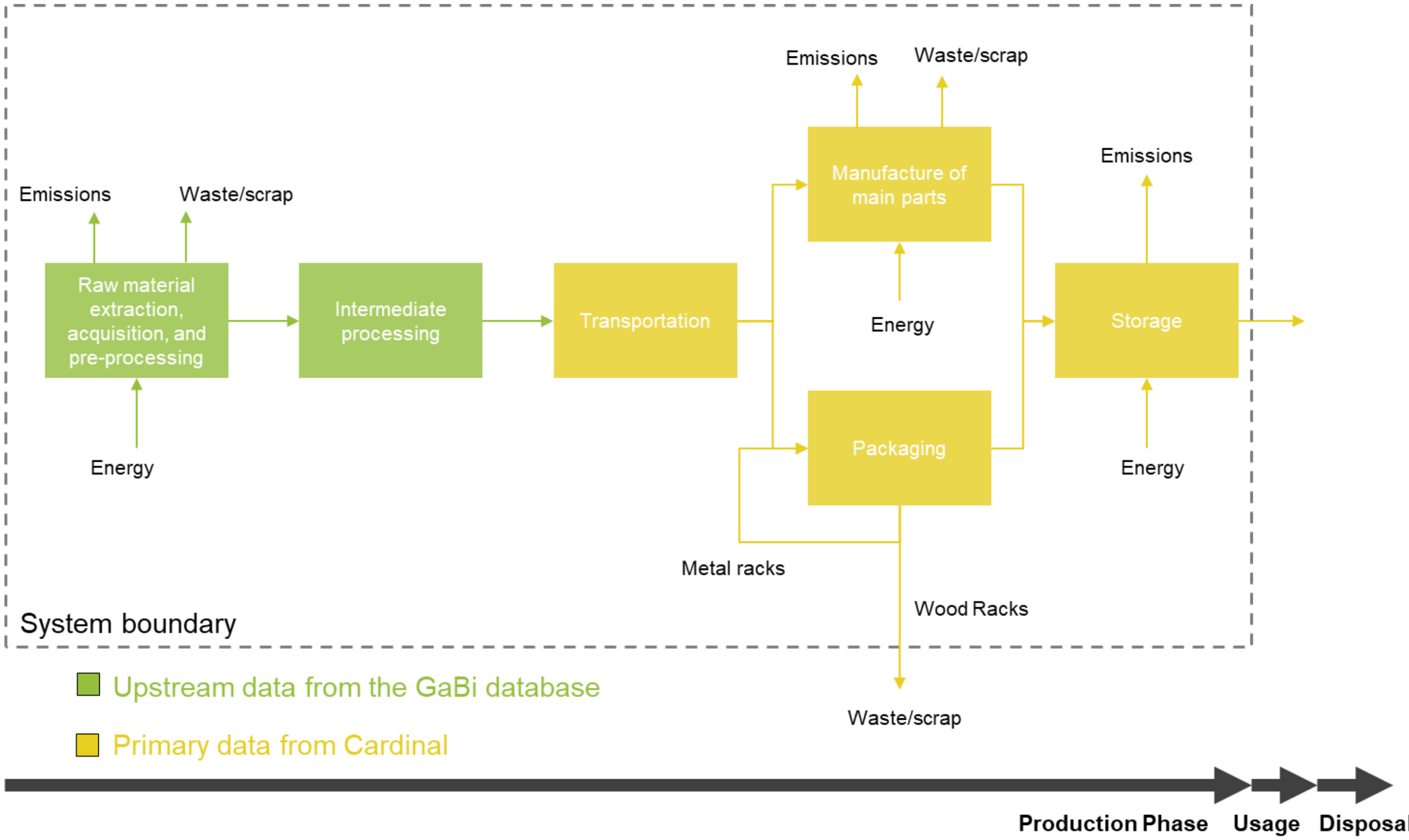


Figure 2-1: Manufacturing process of flat glass from raw materials acquisition through storage

2.2 PACKAGING

The flat 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

One metric tonne of glass maintained for a 30-year period.

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

Mass and energy flows that consist of less than 1% may be omitted from the inventory analysis. Cumulative omitted mass or energy flows shall not exceed 5%. Mass or energy flows that contribute more than 10% to an impact category shall be included.

When the exclusion of inputs and outputs is necessary, the following guidelines shall be followed:

- The calculation shall include all inputs and outputs to a unit process, where data is available. Data gaps may be filled by conservative assumptions with average or generic data. Any assumptions shall be documented in the EPD.
- Where insufficient input data or data gaps for a unit process occur, the cut-off criteria shall be 1% of the total primary energy and 1% of the total mass input of that unit process.
- The EPD shall include a description of the application of cut-off criteria and assumptions and a list of excluded processes.

3.5 DATA SOURCES

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.

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

4 LIFE CYCLE ASSESSMENT RESULTS

Life cycle assessment results are presented per metric tonne of flat glass product. The cradle-to-gate impacts have been broken out into raw material extraction (including inbound transportation) and flat glass production.

Table 4-1: Emissions LCI results for flat glass, per declared unit (1 metric tonne)

Flow	Unit	Raw materials	Production	Total
Emissions to air				
CO_2	kg	391	879	**1,270**
CO	kg	0.210	0.744	**0.958**
Fe	kg	4.53E-05	8.83E-05	**1.34E-04**
CH_4	kg	1.15	2.53	**3.68**
NO_x	kg	0.68	4.77	**5.45**
N_2O	kg	0.00441	0.00936	**0.0138**
NMVOCs	kg	0.0489	0.131	**0.180**
PM (total)	kg	0.240	0.272	**0.512**

Flow	Unit	Raw materials	Production	Total
SO_x	kg	7.79E-26	0.372	**0.372**
Water usage and emissions to water				
Water consumption (net)	m^3	1,400	1,720	**3,130**
Arsenic	kg	6.54E-11	7.48E-10	**8.14E-10**
Cadmium	kg	3.48E-05	6.46E-05	**9.95E-05**
Chromium	kg	1.27E-04	2.47E-04	**3.74E-04**
Lead	kg	5.97E-05	9.74E-05	**1.57E-04**
Mercury	kg	8.68E-07	1.65E-06	**2.52E-06**
NO^{3-}	kg	0.0108	0.0139	**0.0247**
PO_4^{3-}	kg	5.97E-04	7.81E-04	**1.38E-03**
Dioxin	kg	3.96E-18	1.29E-18	**5.25E-18**

Table 4-2: Material and energy usage LCI results for flat glass, per declared unit (1 metric tonne)

Flow	Unit	Raw materials	Production	Total
Renewable primary energy demand, total	MJ	321	416	**736**
Renewable primary energy demand, hydro	MJ	80.0	107	**187**
Renewable primary energy demand, solar	MJ	119	135	**254**
Renewable primary energy demand, wind	MJ	104	168	**272**
Renewable primary energy demand, biomass	MJ	2.19E-18	0.867	**0.867**
Renewable primary energy demand, geothermic	MJ	17.6	5.8	**23.4**
Non-renewable primary energy demand, total	MJ	6,470	12,700	**19,200**
Non-renewable primary energy demand, fossil	MJ	5,980	12,400	**18,400**
Non-renewable primary energy demand, nuclear	MJ	489	271	**760**
Miscellaneous fuels	MJ	-	-	-
Secondary materials	kg	-	-	-

Table 4-3: Wastes and outputs LCI results for flat glass, per declared unit (1 metric tonne)

Flow	Unit	Raw materials	Production	Total
Incineration with energy recovery	kg	-	-	-
Incineration without energy recovery	kg	-	-	-
Non-hazardous waste disposed	kg	45.5	13.0	**58.5**
Hazardous waste disposed	kg	5.58E-06	8.93E-06	**1.45E-05**
Materials for recycling	kg	-	2.40	**2.40**

Table 4-4: LCIA results for flat glass products per functional unit (1 metric tonne)

Impact Category [TRACI 2.1]	Unit	Raw materials	Production	Total
Global Warming Potential	kg CO_2 eq.	421	945	**1,370**
Ozone Depletion Potential[1]	kg CFC-11 eq.	-	-	**-**
Acidification Potential	kg SO_2 eq.	0.861	4.09	**4.95**

[1] ODP values were originally in the order of magnitude of negative 10^{-10}. 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.

Impact Category [TRACI 2.1]	Unit	Raw materials	Production	Total
Eutrophication Potential	kg N eq.	0.0479	0.250	**0.298**
Photochemical Ozone Creation Potential	kg O_3 eq.	17.7	122	**139**
Mineral Resource Depletion Potential	kg Fe eq., per ReCiPe 1.08	2.82	5.72	**8.54**

4.1 SITE-SPECIFIC RESULTS

Cardinal uncoated flat glass is manufactured at five facilities. The results presented in the previous section represent a production-weighted average, by mass. Individual site results are presented below.

Table 4-5: Emissions LCI results for flat glass, per declared unit (1 metric tonne), by site

Type	Flow	Unit	Raw materials	Production	Total
Durant, OK					
Emissions to air	CO2	kg	384	882	**1,270**
	CO	kg	0.19	0.563	**0.753**
	Fe	kg	4.33E-05	8.77E-05	**1.31E-04**
	CH4	kg	1.15	2.54	**3.69**
	NOx	kg	0.59	1.74	**2.33**
	N2O	kg	0.00428	0.0138	**0.0181**
	NMVOCs	kg	0.0393	0.083	**0.123**
	PM (total)	kg	0.238	0.112	**0.35**
	SOx	kg	1.02E-25	0.517	**0.517**
Water usage and emissions to water	Water consumption	m3	1,390	1,310	**2,710**
	Arsenic	kg	6.58E-11	1.25E-09	**1.32E-09**
	Cadmium	kg	2.98E-05	6.50E-05	**9.48E-05**
	Chromium	kg	1.09E-04	2.61E-04	**3.69E-04**
	Lead	kg	5.44E-05	9.34E-05	**1.48E-04**
	Mercury	kg	8.29E-07	1.67E-06	**2.50E-06**
	NO3-	kg	0.0102	0.0143	**0.0244**
	PO43-	kg	4.83E-04	7.58E-04	**1.24E-03**
	Dioxin	kg	3.95E-18	7.82E-19	**4.73E-18**
Menomonie, WI					
Emissions to air	CO2	kg	396	969	**1,360**
	CO	kg	0.2	0.322	**0.522**
	Fe	kg	4.51E-05	9.78E-05	**1.43E-04**
	CH4	kg	1.18	2.77	**3.95**
	NOx	kg	0.61	9.13	**9.74**
	N2O	kg	0.00445	0.00665	**0.0111**
	NMVOCs	kg	0.0427	0.19	**0.233**
	PM (total)	kg	0.245	0.444	**0.69**
	SOx	kg	7.34E-26	0.327	**0.327**
Water usage and emissions to water	Water consumption	m3	1,440	1,680	**3,120**
	Arsenic	kg	6.71E-11	5.06E-10	**5.73E-10**
	Cadmium	kg	3.24E-05	6.79E-05	**1.00E-04**

Type	Flow	Unit	Raw materials	Production	Total
	Chromium	kg	1.18E-04	2.51E-04	**3.69E-04**
	Lead	kg	5.79E-05	1.03E-04	**1.61E-04**
	Mercury	kg	8.67E-07	1.88E-06	**2.75E-06**
	NO3-	kg	0.0108	0.015	**0.0258**
	PO43-	kg	5.42E-04	7.12E-04	**1.25E-03**
	Dioxin	kg	4.12E-18	2.54E-19	**4.38E-18**
Mooresville, NC					
Emissions to air	CO2	kg	371	793	**1,160**
	CO	kg	0.208	0.742	**0.95**
	Fe	kg	4.38E-05	7.81E-05	**1.22E-04**
	CH4	kg	1.07	2.23	**3.3**
	NOx	kg	0.64	1.7	**2.34**
	N2O	kg	0.00415	0.0131	**0.0173**
	NMVOCs	kg	0.0481	0.083	**0.132**
	PM (total)	kg	0.226	0.084	**0.31**
	SOx	kg	8.21E-26	0.399	**0.399**
Water usage and emissions to water	Water consumption	m3	1,310	1,050	**2,360**
	Arsenic	kg	6.06E-11	6.16E-10	**6.76E-10**
	Cadmium	kg	3.79E-05	6.52E-05	**1.03E-04**
	Chromium	kg	1.38E-04	2.46E-04	**3.84E-04**
	Lead	kg	6.12E-05	1.08E-04	**1.69E-04**
	Mercury	kg	8.48E-07	1.48E-06	**2.33E-06**
	NO3-	kg	0.0106	0.0144	**0.0251**
	PO43-	kg	6.76E-04	9.58E-04	**1.63E-03**
	Dioxin	kg	3.63E-18	6.86E-19	**4.31E-18**
Portage, WI					
Emissions to air	CO2	kg	406	926	**1,330**
	CO	kg	0.204	0.521	**0.726**
	Fe	kg	5.14E-05	9.07E-05	**1.42E-04**
	CH4	kg	1.21	2.65	**3.86**
	NOx	kg	0.64	7.89	**8.53**
	N2O	kg	0.00456	0.00655	**0.0111**
	NMVOCs	kg	0.0432	0.215	**0.258**
	PM (total)	kg	0.251	0.381	**0.632**
	SOx	kg	7.02E-26	0.311	**0.311**
Water usage and emissions to water	Water consumption	m3	1,470	1,640	**3,110**
	Arsenic	kg	6.90E-11	6.61E-10	**7.30E-10**
	Cadmium	kg	3.21E-05	6.27E-05	**9.48E-05**
	Chromium	kg	1.17E-04	2.40E-04	**3.58E-04**
	Lead	kg	5.82E-05	9.23E-05	**1.50E-04**
	Mercury	kg	8.81E-07	1.78E-06	**2.66E-06**

Type	Flow	Unit	Raw materials	Production	Total
	NO3-	kg	0.0109	0.0171	**0.028**
	PO43-	kg	5.29E-04	7.84E-04	**1.31E-03**
	Dioxin	kg	4.22E-18	7.93E-20	**4.29E-18**
Winlock, WA					
Emissions to air	CO2	kg	402	847	**1,250**
	CO	kg	0.248	1.53	**1.78**
	Fe	kg	4.37E-05	8.97E-05	**1.33E-04**
	CH4	kg	1.16	2.55	**3.7**
	NOx	kg	0.93	4.95	**5.87**
	N2O	kg	0.00468	0.00503	**0.0097**
	NMVOCs	kg	0.0717	0.108	**0.18**
	PM (total)	kg	0.244	0.413	**0.656**
	SOx	kg	5.68E-26	0.273	**0.273**
Water usage and emissions to water	Water consumption	m3	1,420	3,080	**4,500**
	Arsenic	kg	6.54E-11	6.08E-10	**6.73E-10**
	Cadmium	kg	4.16E-05	6.26E-05	**1.04E-04**
	Chromium	kg	1.52E-04	2.38E-04	**3.90E-04**
	Lead	kg	6.70E-05	9.04E-05	**1.57E-04**
	Mercury	kg	9.23E-07	1.49E-06	**2.42E-06**
	NO3-	kg	0.0116	0.0089	**0.0205**
	PO43-	kg	7.53E-04	6.67E-04	**1.42E-03**
	Dioxin	kg	3.94E-18	4.63E-18	**8.57E-18**

Table 4-6: Energy usage LCI results for float glass, per declared unit (1 metric tonne)

Flow	Unit	Raw materials	Production	Total
Durant, OK				
Renewable primary energy demand, total	MJ	316	520	**836**
Renewable primary energy demand, hydro	MJ	79.7	51	**131**
Renewable primary energy demand, solar	MJ	115	146	**261**
Renewable primary energy demand, wind	MJ	104	317	**421**
Renewable primary energy demand, biomass	MJ	2.86E-18	1.591	**1.591**
Renewable primary energy demand, geothermic	MJ	17.6	3.5	**21.0**
Non-renewable primary energy demand, total	MJ	6,370	12,600	**19,000**
Non-renewable primary energy demand, fossil	MJ	5,890	12,500	**18,400**
Non-renewable primary energy demand, nuclear	MJ	487	142	**629**
Miscellaneous fuels	MJ	-	-	**-**
Secondary materials	kg	-	-	**-**
Menomonie, WI				
Renewable primary energy demand, total	MJ	331	460	**791**
Renewable primary energy demand, hydro	MJ	83.3	53	**136**
Renewable primary energy demand, solar	MJ	121	75	**197**
Renewable primary energy demand, wind	MJ	108	331	**439**
Renewable primary energy demand, biomass	MJ	2.06E-18	0.502	**0.502**
Renewable primary energy demand, geothermic	MJ	18.4	1.1	**19.5**

Flow	Unit	Raw materials	Production	Total
Non-renewable primary energy demand, total	MJ	6,570	13,900	**20,500**
Non-renewable primary energy demand, fossil	MJ	6,060	13,600	**19,700**
Non-renewable primary energy demand, nuclear	MJ	509	291	**801**
Miscellaneous fuels	MJ	-	-	**-**
Secondary materials	kg	-	-	**-**
Mooresville, NC				
Renewable primary energy demand, total	MJ	298	235	**533**
Renewable primary energy demand, hydro	MJ	73.5	31	**105**
Renewable primary energy demand, solar	MJ	113	174	**287**
Renewable primary energy demand, wind	MJ	95	25	**121**
Renewable primary energy demand, biomass	MJ	2.31E-18	0.696	**0.696**
Renewable primary energy demand, geothermic	MJ	16.1	3.0	**19.2**
Non-renewable primary energy demand, total	MJ	6,120	11,800	**17,900**
Non-renewable primary energy demand, fossil	MJ	5,670	11,000	**16,700**
Non-renewable primary energy demand, nuclear	MJ	448	725	**1173**
Miscellaneous fuels	MJ	-	-	**-**
Secondary materials	kg	-	-	**-**
Portage, WI				
Renewable primary energy demand, total	MJ	338	259	**597**
Renewable primary energy demand, hydro	MJ	85.2	57	**143**
Renewable primary energy demand, solar	MJ	123	154	**278**
Renewable primary energy demand, wind	MJ	111	46	**157**
Renewable primary energy demand, biomass	MJ	1.97E-18	0.738	**0.738**
Renewable primary energy demand, geothermic	MJ	18.8	0.4	**19.1**
Non-renewable primary energy demand, total	MJ	6,730	13,100	**19,800**
Non-renewable primary energy demand, fossil	MJ	6,210	13,000	**19,200**
Non-renewable primary energy demand, nuclear	MJ	521	80	**601**
Miscellaneous fuels	MJ	-	-	**-**
Secondary materials	kg	-	-	**-**
Winlock, WA				
Renewable primary energy demand, total	MJ	324	614	**938**
Renewable primary energy demand, hydro	MJ	79.9	348	**428**
Renewable primary energy demand, solar	MJ	123	110	**234**
Renewable primary energy demand, wind	MJ	103	135	**238**
Renewable primary energy demand, biomass	MJ	1.60E-18	0.659	**0.659**
Renewable primary energy demand, geothermic	MJ	17.6	20.6	**38.1**
Non-renewable primary energy demand, total	MJ	6,630	12,400	**19,000**
Non-renewable primary energy demand, fossil	MJ	6,140	12,300	**18,500**
Non-renewable primary energy demand, nuclear	MJ	487	85	**572**
Miscellaneous fuels	MJ	-	-	**-**
Secondary materials	kg	-	-	**-**

Table 4-7: Wastes and outputs LCI results for flat glass, per declared unit (1 metric tonne)

Flow	Unit	Raw materials	Production	Total
Durant, OK				
Incineration with energy recovery	kg	-	-	**-**
Incineration without energy recovery	kg	-	-	**-**

Flow	Unit	Raw materials	Production	Total
Non-hazardous waste disposed	kg	45.7	18.1	**63.8**
Hazardous waste disposed	kg	4.52E-06	**8.32E-06**	1.28E-05
Materials for recycling	kg	-	-	**-**
Menomonie, WI				
Incineration with energy recovery	kg	**-**	**-**	-
Incineration without energy recovery	kg	-	-	-
Non-hazardous waste disposed	kg	47.0	17.4	**64.4**
Hazardous waste disposed	kg	5.04E-06	1.00E-05	**1.51E-05**
Materials for recycling	kg	-	2.85	**2.85**
Mooresville, NC				
Incineration with energy recovery	kg	**-**	**-**	-
Incineration without energy recovery	kg	-	-	-
Non-hazardous waste disposed	kg	41.9	11.4	**53.3**
Hazardous waste disposed	kg	6.33E-06	9.36E-06	**1.57E-05**
Materials for recycling	kg	-	-	**-**
Portage, WI				
Incineration with energy recovery	kg	**-**	**-**	-
Incineration without energy recovery	kg	-	-	-
Non-hazardous waste disposed	kg	48.2	9.33	**57.5**
Hazardous waste disposed	kg	4.94E-06	9.01E-06	**1.39E-05**
Materials for recycling	kg	-	4.42	**4.42**
Winlock, WA				
Incineration with energy recovery	kg	**-**	**-**	-
Incineration without energy recovery	kg	-	-	-
Non-hazardous waste disposed	kg	45.4	8.69	**54.1**
Hazardous waste disposed	kg	7.05E-06	8.17E-06	**1.52E-05**
Materials for recycling	kg	-	5.49	**5.49**

Table 4-8: LCIA results for flat glass products per functional unit (1 metric tonne)

Flow [TRACI 2.1]	Unit	Raw materials	Production	Total
Durant, OK				
Global Warming Potential	kg CO_2 eq.	414	950	**1,360**
Ozone Depletion Potential[2]	kg CFC-11 eq.	-	-	**-**
Acidification Potential	kg SO_2 eq.	0.791	2.21	**3.01**
Eutrophication Potential	kg N eq.	0.0425	0.129	**0.172**
Photochemical Ozone Creation Potential	kg O_3 eq.	15.2	46.2	**61.4**
Mineral Resource Depletion Potential	kg Fe eq., per ReCiPe 1.08	2.74	5.70	**8.45**
Menomonie, WI				
Global Warming Potential	kg CO_2 eq.	427	1,040	**1,470**
Ozone Depletion Potential[2]	kg CFC-11 eq.	-	-	**-**
Acidification Potential	kg SO_2 eq.	0.833	7.09	**7.92**

[2] ODP values were originally in the order of magnitude of negative 10^{-10}. 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.

Flow [TRACI 2.1]	Unit	Raw materials	Production	Total
Eutrophication Potential	kg N eq.	0.0453	0.437	**0.482**
Photochemical Ozone Creation Potential	kg O_3 eq.	16.2	230	**246**
Mineral Resource Depletion Potential	kg Fe eq., per ReCiPe 1.08	2.84	6.36	**9.2**
Mooresville, NC				
Global Warming Potential	kg CO_2 eq.	399	853	**1,250**
Ozone Depletion Potential[2]	kg CFC-11 eq.	-	-	**-**
Acidification Potential	kg SO_2 eq.	0.840	2.01	**2.85**
Eutrophication Potential	kg N eq.	0.0480	0.129	**0.177**
Photochemical Ozone Creation Potential	kg O_3 eq.	17.4	46.9	**64.3**
Mineral Resource Depletion Potential	kg Fe eq., per ReCiPe 1.08	2.67	5.1	**7.77**
Portage, WI				
Global Warming Potential	kg CO_2 eq.	437	994	**1,430**
Ozone Depletion Potential[2]	kg CFC-11 eq.	-	-	**-**
Acidification Potential	kg SO_2 eq.	0.841	6.15	**6.99**
Eutrophication Potential	kg N eq.	0.0454	0.381	**0.426**
Photochemical Ozone Creation Potential	kg O_3 eq.	16.4	199	**215**
Mineral resource Depletion Potential	kg Fe eq., per ReCiPe 1.08	3.13	5.77	**8.9**
Winlock, WA				
Global Warming Potential	kg CO_2 eq.	432	913	**1,340**
Ozone Depletion Potential[2]	kg CFC-11 eq.	-	-	**-**
Acidification Potential	kg SO_2 eq.	1.01	4.01	**5.02**
Eutrophication Potential	kg N eq.	0.0585	0.241	**0.300**
Photochemical Ozone Creation Potential	kg O_3 eq.	23.4	125	**149**
Mineral Resource Depletion Potential	kg Fe eq., per ReCiPe 1.08	2.73	5.86	**8.59**

5 LCA Interpretation

The analysis results represent the cradle-to-gate environmental performance of uncoated flat glass products. For a better understanding of the results and impact drivers for the product of uncoated glass, the environmental performance is further broken down in Figure 5-1 as follows:

- **Composition materials** - upstream impacts associated with extraction and pre-processing of materials used in glass manufacture and processing, including silica sand, dolomite, etc.
- **Process materials** - upstream impacts associated with extraction and pre-processing of process materials like oxygen, hydrogen, nitrogen, tin bath, etc.
- **Electricity** - impacts associated with generating electricity in relevant manufacturing facility regions
- **Natural gas** - impacts associated with natural gas production for use in the furnace and direct emissions from combustion
- **Inbound transport** - ship, rail, and truck transport of materials to the manufacturing facilities, including intermediate transport between Cardinal facilities
- **Direct emissions** - emissions reported by facilities (excludes fuel combustion both on-site and for electricity generation)
- **Miscellaneous** - impacts associated with manufacturing waste, packaging materials, water usage, and onsite transport

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

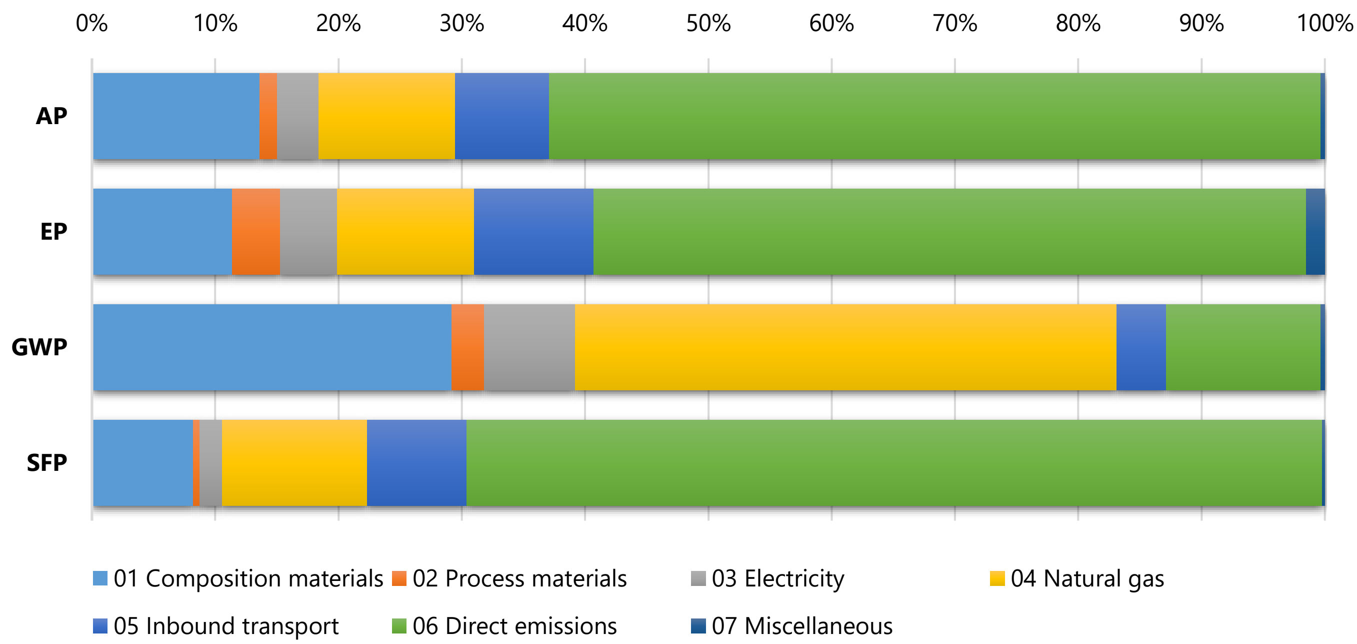


Figure 5-1: Relative contributions of manufacturing inputs and outputs for uncoated glass production (TRACI 2.1)

Direct reported emissions drive many impact categories, including acidification potential, eutrophication potential, and smog formation potential. This is due to direct emissions of nitrogen oxides. Global warming potential is driven primarily by natural gas production and combustion, upstream production and extraction of soda and sand, process CO_2 emissions, and electricity consumption.

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.

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