Environmental Product Declaration

According to ISO 14025

Flat Glass

This EPD was not written to support comparative assertions. Even for similar products, differences in declared unit, use and end-of-life stage assumptions, and data quality may produce incomparable results. It is not recommended to compare EPDs with another organization, as there may be differences in methodology, assumptions, allocation methods, data quality such as variability in data sets, and results of variability in assessment software tools used.

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Declaration Information

Declaration

Program Operator: ASTM International	www.astm.org	glass.org
Company: National Glass Association		

Product Information / Validity / Applicability

Product Information	Validity / Applicability
Product Name: Flat glass	**Period of Validity:** This declaration is valid for a period of 5 years from the date of publication
Product Definition: Industry average flat glass, including clear, tinted, and low-iron products	
Declaration Type: Business to business	**Geographic Scope:** This declaration is valid for products sold in the United States
PCR Reference: GANA PCR for Flat Glass: UN CPC 3711	

Product Application and / or Characteristics

Flat glass is used as a transparent architectural glazing material in the building envelope. It provides safety, security, thermal comfort, acoustical comfort, daylighting and views for buildings.

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
- Life Cycle Assessment results

Product Information / Validity / Applicability

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

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EPD Summary

This document is a Type III environmental product declaration by the National Glass Association (NGA) that is certified by ASTM International (ASTM) as conforming to the requirements of ISO 14025. ASTM has assessed that the Life Cycle Assessment (LCA) information fulfills the requirements of ISO 14040 and ISO 14044 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.

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 (National Center for Sustainability Standards, 2019).

System Boundary: Cradle-to-gate
Allocation Method: Cut-off approach
Declared Unit: One metric tonne (1,000 kg) of flat glass, maintained for a 30-year period

EVALUATION VARIABLE	UNIT PER METRIC TONNE	TOTAL
Global warming potential	kg CO_2 eq.	1.43E+03
Acidification potential	kg SO_2 eq.	6.59E+00
Eutrophication potential	kg N eq.	3.49E-01
Ozone depletion potential	kg CFC-11 eq.	2.48E-09
Smog formation potential	kg O_3 eq.	1.68E+02
Mineral resource depletion potential	kg Fe eq.	1.42E+01

Flat Glass | EPD - 121

Industry Association Description

Founded in 1948, the National Glass Association (NGA) combined with the Glass Association of North America (GANA) on February 1, 2018 to form the largest trade association serving the architectural glass and metals industry supply chain, including glazing contractors, full-service glass companies, glass fabricators, primary glass manufacturers and suppliers to the industry. It is a technical powerhouse that brings some of the best minds to the table to create technical resources and to promote and advocate for glass in buildings. NGA's education and training resources—both in print and online at **MyGlassClass.com**—as well as its official publications **Glass Magazine** and **Window & Door**, keep the industry knowledgeable and well-informed. NGA produces the industry's largest annual trade show in the Americas, **GlassBuild America**, hosts the following **events**: Annual Conference, Building Envelope Contractors (BEC) Conference, Fall Conference, the Glazing Executives Forum, and is a co-sponsor of **Glass Processing Automation Days** (GPAD).

This EPD covers flat glass produced by four NGA member companies. The member companies that participated in the study are AGC Glass North America, Guardian Industries, NSG Group, and Vitro Architectural Glass.

Product Description

Flat glass is a general term that describes all glass produced in a flat form, such as float glass, sheet glass, plate glass and rolled glass. It is formulated from soda-lime silicates and metal-oxide materials. Flat glass is manufactured by mixing raw materials at high temperature and floating them onto the surface of a molten tin bath, which smooths the glass by gravity and surface tension. The flat glass ribbon is guided on rollers through an annealing lehr where it is cooled under controlled conditions to avoid buildup of internal stress until it emerges at essentially room temperature. The resulting flat glass is cut to desired sizes and is available in a range of thicknesses and surface treatment options.

The declared flat glass products are installed as windows, glass doors and glass walls in commercial, institutional and residential buildings specified by architects, glazing contractors and window manufacturers. Flat glass in buildings provides daylight and views, benefitting building occupants with improved productivity, enhanced mood and health, and increased real estate values. Glass also enhances the safety and security of buildings, providing a sense of connection to the community outside. Flat glass products can be designed to protect building occupants during natural and manmade events, and to reduce energy requirements for heating and cooling the building.

Product Applicability and Technical Characteristics

This declaration is valid for clear, low-iron, and tinted glass products that have been manufactured in an unprocessed annealed state. Glass that has been coated, heat-treated, or undergone any secondary processing are not within the scope of this declaration. Flat glass is primarily used as a transparent building material for interior and exterior application in the architectural market.

Flat glass is defined by the following standards:

- ASTM C1036: Standard Specification for Flat Glass
- Standard 1

Additional information can be found on the National Glass Association's website at www.glass.org.

Life Cycle Stages

The life cycle stages for flat glass are summarized in the flow diagram shown in the figure below. Only the cradle-to-gate performance is considered in the analysis.

Figure 1: Life cycle modules included in analysis

Raw Material Acquisition and Transportation

Flat glass is manufactured from raw materials such as silica sand, soda ash, dolomite, limestone and cullet. The crystalline raw materials chemically and structurally transform into amorphous glass through a fusion (melting) process, thereby producing a product which is >99.9% glass oxide. The data collected from participating manufacturers were combined using a mass-based production weighted average to represent industry production for the year 2015. Table 1 shows the production-weighted average raw material ingredients of flat glass manufacture. Facilities provided data for all flat glass production, including clear, tinted, and low-iron products. Tint materials, however, would have no impact on the final results and were therefore excluded from the study.

Table 1: Raw material ingredients of flat glass

Material	Mass [%]
Silica sand	55%
Limestone	5.0%
Soda ash	21%
Dolomite	14%
Sodium sulphate	<1%
Sodium nitrate	<0.1%
Iron Oxide	<0.1%
Carbon	<0.1%
Other	4.3%

Average transportation distances and modes of transport are used for the transport of raw materials, process materials, and auxiliary material to production facilities. The manufacturing stage includes the inbound transport of packaging materials to the manufacturing facility, while raw material transport is included under the raw materials extraction and pre-processing stage.

Production

Flat glass is made by floating molten glass on a bed of molten tin. Once raw materials are at the manufacturing facility, they are mixed, refined, melted, and flowed over a refractory spout onto the molten tin bath. The glass is guided on rollers over the tin and through an annealing lehr. The glass is cooled in the lehr under controlled conditions and emerges at room temperature. After cooling, the glass is either treated or cut to size as specified by the end user.

Underlying Life Cycle Assessment

Declared Unit

The declared unit for this EPD is one metric tonne of flat glass maintained for a 30-year period. Note that comparison of EPD results on a mass basis, alone, is insufficient and should consider the technical performance of the product.

Name	Required unit
Declared unit	Metric tonne maintained for a 30-year period

System Boundaries

The "cradle-to-gate" life cycle stages represent the product stage include:

- **Material Extraction and Pre-Processing –** Extraction and processing of raw materials, including inbound transport of these materials to the glass manufacturing facility
- **Production –** Manufacturing of flat glass from raw materials and packaging materials. This stage concludes at the "gate" (i.e. where 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.

This EPD represents flat glass production by participating NGA member companies produced during 2015.

Assumptions

Due to limitations in data availability, some assumptions were made in allocating important manufacturing inputs and outputs including electricity, process materials, and natural gas at facilities where flat glass production and coating and thermal treatment processes all occur. Any treatments or coatings are outside of the system boundary of flat glass manufacturing and therefore outside the scope of this analysis. The allocation approaches taken may therefore overestimate the environmental burden for uncoated glass production and underestimate that of glass processing steps as many of these inputs and outputs were allocated entirely to uncoated glass production.

Cut-off Criteria

The cut-off criteria follow guidelines laid out in the PCR. The system boundary was defined based on relevance to the goal of the study. For the processes within the system boundary, all available energy and material flow data were included in the model, with the exception of tints where the mass was so small that their impact would have been insignificant. In cases where no matching life cycle inventories were available to represent a flow, proxy data were applied based on conservative assumptions regarding environmental impacts.

Data Quality

A variety of tests and checks were performed throughout the project to ensure high quality of the completed LCA. Checks included an extensive review of the LCA model as well as of the background data used.

Temporal Representativeness

All primary data were collected for the years 2015-2016. All secondary data come from the GaBi 2019 databases and are representative of the years 2016-2018. As the study intended to compare the product systems for the reference year 2015, temporal representativeness is considered to be high.

Geographical Representativeness

All primary and secondary data were collected specific to the countries or regions under study. Where country-specific or region-specific data were unavailable, proxy data were used. Proxies were not used for inputs that contribute significantly to impacts, therefore geographical representativeness is considered to be high.

Technological Representativeness

All primary and secondary data were modeled to be specific to the technologies or technology mixes under study. Where technology-specific data were unavailable, proxy data were used. Proxies were not used for inputs that contribute significantly to impacts, therefore technological representativeness is considered to be high.

Precision

As the majority of the relevant foreground data are measured data or calculated based on primary information sources of the owner of the technology, precision is considered to be high. Seasonal variations were balanced out by using yearly averages. All background data are sourced from GaBi databases with the documented precision.

Completeness

Each foreground process was checked for mass balance and completeness of the emission inventory. With the exception of tints where the impacts were assumed to be negligible, no data were knowingly omitted. Completeness of foreground unit process data is considered to be high. All background data are sourced from GaBi databases with the documented completeness.

Consistency

To ensure data consistency, all primary data were collected with the same level of detail, while all background data were sourced from the GaBi databases.

Reproducibility

Reproducibility is supported as much as possible through the disclosure of input-output data, dataset choices, and modeling approaches in the background EPD report. Based on this information, any third party with access to the background report should be able to approximate the results of this study using the same data and modeling approaches.

Allocation

Flat glass production is not a multi-output process; thus, no multi-output allocation was needed for this project. All environmental burdens associated with the manufacturing process were assigned to the flat glass product. Where other processes occurred at the flat glass facility, energy, water, emissions, and wastes needed to be allocated to flat glass production. Depending on available data, either the per ton or m^2 inputs/outputs for the processing step or the per ton impacts of the company's other sites for flat glass production were used to reduce the inputs/outputs to just those attributed to flat glass production. End-of-life allocation generally follows the requirements of ISO 14044, section 4.3.4.3. The study follows a cut-off approach.

LCA Results

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. Primary energy use represents lower heating value.

Table 2: Emissions LCI results per 1 metric tonne

Type	Flow	Unit	Raw materials	Production	Total
Emissions to air	SO_x	kg	4.62E-01	1.22E+00	**1.69E+00**
	NO_x	kg	6.68E-01	5.96E+00	**6.63E+00**
	CO_2	kg	5.07E+02	8.26E+02	**1.33E+03**
	CO	kg	2.96E-01	4.22E-01	**7.18E-01**
	NMVOCs	kg	9.42E-02	2.73E-01	**3.67E-01**
	Fe	kg	9.06E-05	1.54E-04	**2.44E-04**
	PM (total)	kg	1.82E-01	1.15E+00	**1.33E+00**
Water usage and emissions to water	Water consumption	m^3	1.53E+03	1.11E+03	**2.64E+03**
	PO_4^{3-}	kg	7.74E-04	4.45E-04	**1.22E-03**
	NO^{3-}	kg	1.29E-02	1.20E-02	**2.48E-02**
	Dioxin	kg	4.06E-18	4.82E-18	**8.88E-18**
	Arsenic	kg	3.74E-11	2.61E-06	**2.61E-06**
	Lead	kg	1.44E-04	9.50E-05	**2.39E-04**
	Mercury	kg	1.01E-06	1.65E-06	**2.66E-06**
	Cadmium	kg	5.97E-05	5.15E-05	**1.11E-04**
	Chromium	kg	7.54E-03	2.18E-04	**7.75E-03**

Table 3: Energy usage LCI results per 1 metric tonne

Flow	Unit	Raw Materials	Production	Total
Primary energy demand	MJ	7.25E+03	1.44E+04	**2.16E+04**
Fossil fuels	MJ	6.40E+03	1.34E+04	**1.98E+04**
Nuclear	MJ	5.05E+02	5.39E+02	**1.04E+03**
Solar	MJ	1.31E+02	1.42E+02	**2.73E+02**
Wind	MJ	1.08E+02	1.43E+02	**2.51E+02**
Hydropower	MJ	8.50E+01	5.88E+01	**1.44E+02**
Biomass	MJ	6.64E-10	5.15E+00	**5.15E+00**

Table 4: Waste management LCI results per 1 metric tonne

Flow	Unit	Raw Materials	Production	Total
Incineration with energy recovery	kg	-	1.20E-03	**1.20E-03**
Incineration without energy recovery	kg	-	-	**-**
Landfill (non-hazardous solid waste)	kg	4.31E+01	2.48E+01	**6.78E+01**
Hazardous waste	kg	1.83E-05	6.30E-06	**2.46E-05**
Landfill avoidance (recycling)	kg	-	2.87E+01	**2.87E+01**

Table 5: Life cycle impact assessment results per 1 metric tonne

Impact Category	Unit	Raw Materials	Production	Total	Methodology
GWP	kg CO_2 eq.	5.34E+02	8.96E+02	**1.43E+03**	TRACI 2.1
AP	kg SO_2 eq.	1.11E+00	5.48E+00	**6.59E+00**	
EP	kg N eq.	6.35E-02	2.86E-01	**3.49E-01**	
ODP	kg CFC-11 eq.	7.22E-10	4.93E-11	**7.71E-10**	
SFP	kg O_3 eq.	1.93E+01	1.48E+02	**1.68E+02**	
Metal depletion	kg Fe eq.	7.86E+00	6.37E+00	**1.42E+01**	ReCiPe 2008

LCA Interpretation

Visualization of Life Cycle Impact Assessment

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

- **Batch materials** - upstream impacts associated with extraction and pre-processing of materials used in glass manufacture, including silica sand, dolomite, pigments, 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 and combustion for use in the furnace
- **Inbound transport** - ship, rail, and truck transport of raw materials to the manufacturing facilities
- **Direct emissions** – process emissions reported by facilities
- **Miscellaneous** - impacts associated with manufacturing waste, packaging materials, water usage, and onsite transport

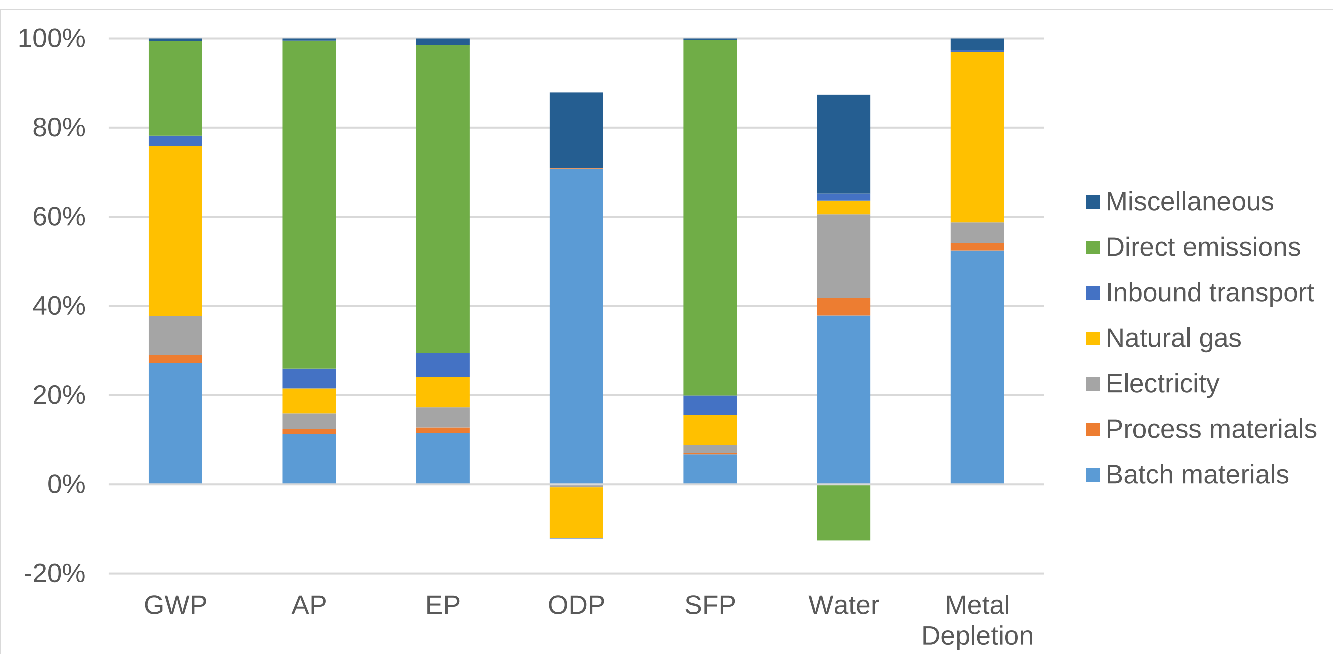

Figure 2: Relative contribution of manufacturing inputs and outputs to impact assessment results

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