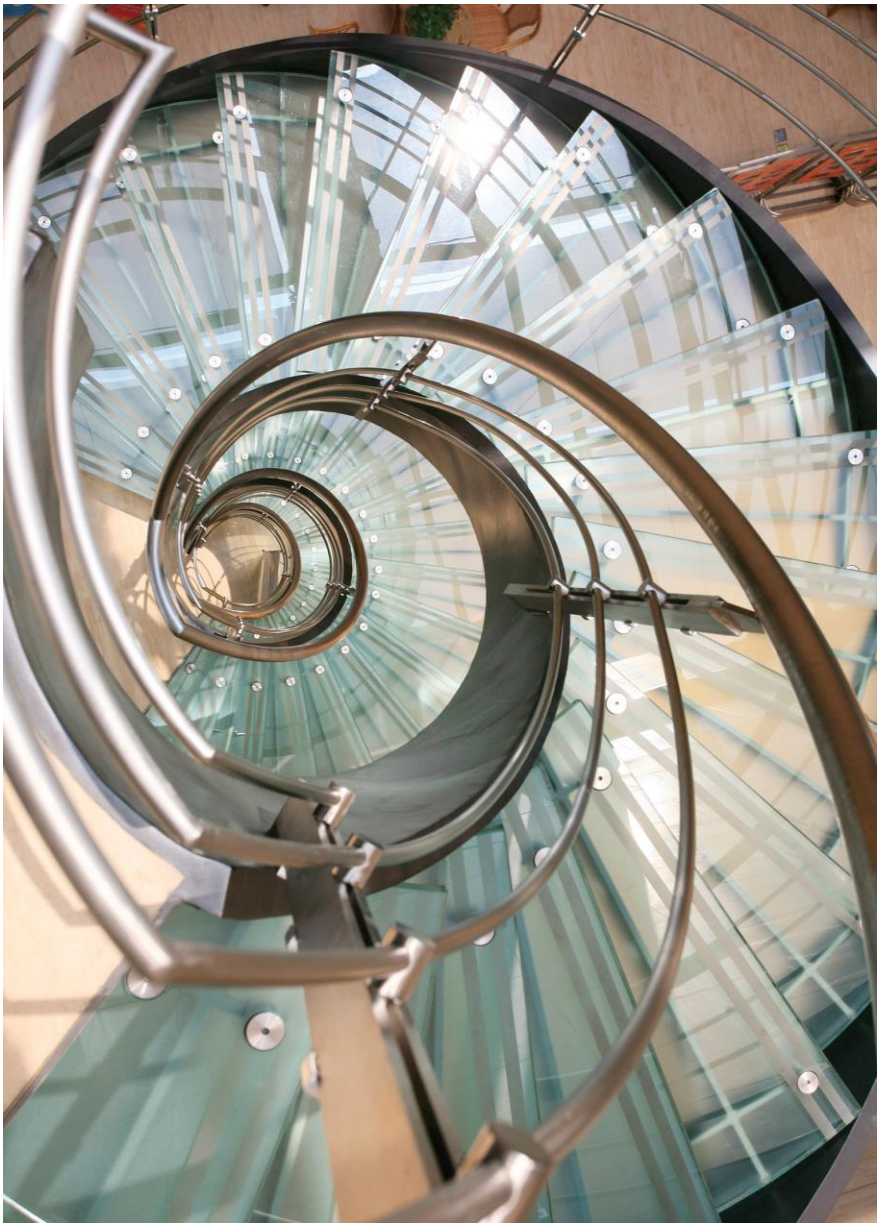
ENVIRONMENTAL PRODUCT DECLARATION

FLAT GLASS PRODUCTS

GUARDIAN GLASS



Guardian Glass is dedicated to continually improving the science and process of its core competency, flat glass manufacturing.

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.

Guardian Glass is committed to the efficient use of natural resources while operating in a way that protects the safety, health and well-being of its employees, customers, the environment and society.

As a manufacturing leader of high performance, energy-efficient glass products for commercial, residential, interior, transportation and specialty applications, Guardian Glass makes products that help improve people's lives. By allowing abundant natural light into homes, offices and vehicles, glass products can help contribute to occupants' well-being and low-emissivity glass reduces energy consumption for heating and cooling.

By publishing this EPD, Guardian Glass intends to support architects and designers who strive to enhance the sustainability profiles of the buildings they design through the products they specify. The goal is to provide them with the information needed to achieve credits in global green building rating systems.

UL CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION UL.COM/EPD

ENVIRONMENTAL PRODUCT DECLARATION

GUARDIAN GLASS

According to ISO 14025, ISO 21930:2007 & EN 15804

GUARDIAN FLAT GLASS PRODUCTS

This declaration is an environmental product declaration (EPD) in accordance with ISO 14025. EPDs rely on Life Cycle Assessment (LCA) to provide information on a number of environmental impacts of products over their life cycle. Exclusions: EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, environmental impact assessments, etc. Accuracy of Results: EPDs regularly rely on estimations of impacts, and the level of accuracy in estimation of effect differs for any particular product line and reported impact. Comparability: EPDs are not comparative assertions and are either not comparable or have limited comparability when they cover different life cycle stages, are based on different product category rules or are missing relevant environmental impacts. EPDs from different programs may not be comparable.

PROGRAM OPERATOR	UL Environment
DECLARATION HOLDER	Guardian Glass
DECLARATION NUMBER	4788140764.101.1
DECLARED PRODUCT	Flat Glass Products
REFERENCE PCR	NSF- GANA PCR for Flat Glass: UN CPC 3711 (2014)
DATE OF ISSUE	September 5, 2018
PERIOD OF VALIDITY	5 Years
CONTENTS OF THE DECLARATION	▪ Product definition and information about building physics ▪ Information about basic material and the material's origin ▪ Description of the product's manufacture ▪ Indication of product processing ▪ Information about the in-use conditions ▪ Life cycle assessment results ▪ Testing results and verifications

The PCR review was conducted by:	PCR Review Panel Thomas Gloria ncss@nsf.org
This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories ☐ INTERNAL ☒ EXTERNAL	Grant R. Martin Grant R. Martin, UL Environment
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	Thomas S. Gloria Thomas P. Gloria, Industrial Ecology Consultants

This EPD conforms with ISO 21930:2007 & EN 15804

Product System

Company Description

Guardian Glass strives to be the go-to solutions provider for the global glass industry, whether it's to solve a practical problem or challenge architectural conventions. With the infrastructure, know-how and capability to work with the entire supply chain, Guardian Glass embraces a future where glass is an even greater part of what the world builds. Guardian Glass helps designers and specifiers of glass realize their vision, overcome obstacles and be partners in the development of world-class structures.

Headquartered in Auburn Hills, Michigan, Guardian Glass is one of the world's largest glass manufacturers with leading positions in float and fabricated glass products for commercial, residential, interior, technical and transportation applications. Guardian strives to constantly innovate to create value and to create value for customers and society.

Guardian Glass believes that environmentally responsible building is the right thing to do and the company is proud to be a member of the U.S. Green Building Council – a coalition of building industry leaders that promotes and creates environmentally responsible structures.

Guardian Glass is part of Guardian Industries, a standalone, wholly-owned subsidiary of Koch Industries, Inc. Koch companies conduct their worldwide operations in compliance with all relevant environmental laws and regulations, while protecting the health and safety of their customers, employees and neighbors. In 2017, Koch was awarded the U.S. Environmental Protection Agency's ENERGY STAR Partner of the Year Award.

Guardian, and its companies, take pride in creating a work environment that recognizes and celebrates individuality, teamwork and success. The foundation of Guardian's culture rests upon the Guiding Principles within Market Based Management®. The company's entrepreneurial spirit encourages employees to think bigger and creates opportunities to learn from and collaborate with very skilled and knowledgeable mentors. For example, the dedicated scientists and engineers at the Guardian Glass Science & Technology Center are constantly working to create new glass products and solutions using the most advanced technologies.

Product Description

This EPD is valid for the following flat unprocessed Guardian Glass products:

- Clear Glass
- Ultra Clear™ Low-Iron Glass
- Green Glass
- TwilightGreen® Glass
- Gray Glass
- CrystalGray® Glass
- CrystalBlue™ Glass
- MidnightGray™ Glass
- MidnightGray® II Glass
- PrivaGuard® Glass
- Solar Management Glass (SMG®) – SMG II, SMG III, SMG IV

For more information about these products, please visit www.guardianglass.com or email info@guardianglass.com.

Application

Flat glass products are used in applications ranging from equipment components to transportation vehicles and architectural products. Guardian Glass typically supplies float glass and coated glass to fabricator customers who further process that glass into the final product by cutting, heat-treating, laminating, insulating or otherwise fabricating the glass into the desired size and makeup for use in the intended application. The glass makeup is typically specified by architects, glazing contractors, window manufacturers and other design professionals.

Technical Data

Technical data on Guardian Glass products is available on at www.guardianglass.com

Properties of Declared Product as Delivered

Product Sizes: While products are primarily cut to customers' specified dimensions, common dimensions of flat glass include:

- 72" x 84"
- 72" x 96"
- 96" x 130"
- 102" x 144"
- 130" x 204"

While thickness of glass also varies based on customer needs, some standard thicknesses for flat glass include:

- 1.6mm
- 2.3mm
- 2.5mm
- 2.7mm
- 3.0mm
- 3.1mm
- 3.2mm
- 4.0mm
- 5.0mm
- 6.0mm
- 8.0mm
- 10.0mm
- 12.0mm
- 15.0mm
- 19.0mm

Declaration Type: Business-to-business

Period of Validity: 5 years

Geographic Scope: This declaration is valid for flat glass products sold in North America from Guardian Glass.

Additional Notes: Further processing of the flat glass, such as coating, tempering, laminating, etc., are beyond the scope of the PCR and as such, not included in this analysis. Please see a separate EPD from Guardian Glass for processed glass products. Additionally, this analysis represents the performance of a production-weighted average of Guardian flat glass products, based on 2016 production volumes.

Placing on the Market

The products validated in this EPD conform to the following technical specifications for flat glass products:

- ASTM C 1036: Standard Specification for Flat Glass

Product Formulation

Float glass is made by floating molten glass on a bed of molten tin. It 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. Guardian tinted and patterned glass are similar in composition to clear float glass but may include slight variations of trace elements to achieve required optical properties.

Manufacture

Flat glass production involves heating the raw materials to a liquid state and then floating the subsequent ribbon of glass atop a bath of molten tin. Once the ribbon has sufficiently cooled, it is transferred onto rollers and annealed to limit residual stresses. Its edges are trimmed and the ribbon is cut to the desired sizes. The finished flat glass products are stored for additional processing (e.g., heat-treating or coating) or directly packaged and shipped to customers.

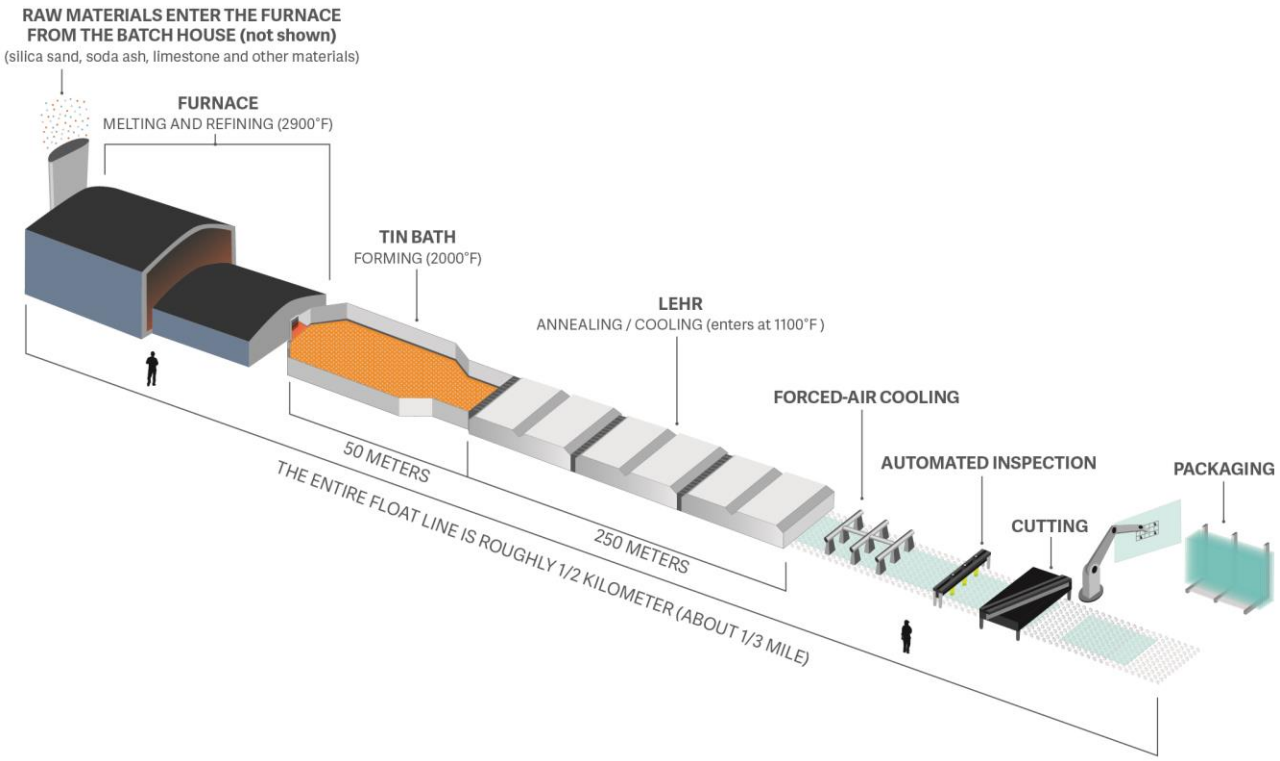


Figure 1: Flat glass production

Manufacturing of flat glass products in North America takes place at Guardian Glass facilities located in Carleton, MI; Corsicana, TX; DeWitt, IA; Geneva, NY; Kingsburg, CA; Richburg, SC; and El Marques, Queretaro, Mexico. The primary raw material for glass is silica sand, and most Guardian Glass float plants are within 200 miles of their sand supply, which reduces energy spent and emissions in transit to the manufacturing plant.

Environment and Health during Manufacturing

Guardian Glass implements measures to reduce waste and reuse/recycle materials internally within its manufacturing processes. Consistent with industry practice, batch ingredients include “cullet”, broken glass from prior in-plant ribbon-trimming operations and other potential sources. A limited amount of cullet from outside the plant may be implemented if it complies with Guardian’s rigorous quality criteria. The use of cullet helps to moderate consumption of batch materials and furnace fuel, both affecting carbon dioxide (CO_2) emissions.

Guardian Glass benefits from recycling in several ways: recycled glass reduces CO_2 process emissions and consumption of virgin raw materials; extends the life of plant equipment (such as furnaces); and saves energy. Recycled glass is always part of the recipe for glass, and the more that is used, the greater the decrease in energy used in the furnace. This makes using recycled glass profitable in the long run – lowering costs and benefiting the environment while ensuring greater product sustainability without negatively impacting quality.

Product Processing / Installation

Guardian Glass products should be processed and installed according to best industry standards and according to all applicable building codes in the given jurisdiction.

Packaging

Guardian Glass products are primarily packaged on reusable steel racks. Racks used for distribution of glass are reused many times both in the manufacturing plants and shipped to the customer and subsequently returned to Guardian Glass float plants. The greatest risks associated with the handling and storage of float glass are lacerations from cut/broken glass and injury from falling glass. Serious injuries and fatalities may result from improper handling and transportation of float glass. It is imperative that all persons involved with these activities receive proper training, wear adequate personal protective equipment and adhere to all best handling guidelines and safety procedures.

Conditions of Use

Flat glass products are used in applications ranging from equipment components to transportation vehicles and architectural products. Guardian Glass typically supplies float glass and coated glass to fabricator customers who further process that glass into the final product by cutting, heat-treating, laminating, insulating or otherwise fabricating the glass into the desired size and makeup for use in the intended application.

Environment and Health during Use

The life cycle assessment is conducted for a cradle-to-gate system boundary, per NSF GANA Product Category Rule (PCR) for Flat Glass – UNCPC 3711. Life cycle stages and environmental impacts downstream of Guardian’s North America float glass facilities are not included in this declaration. Additionally, transportation to waste or scrap facilities is excluded from the system, as are capital goods, infrastructure, and personnel-related activities.

Reference Service Life

Guardian flat glass products satisfy the 30-year service life requirement as defined by the Glass Association of North America (GANA) Product Category Rule (PCR) for Flat Glass.

Distribution, Use, and End-of-Life

Upon leaving Guardian Glass facilities, flat glass can be further processed through a nationwide network of independent fabricators.

Racks used for distribution of glass are reused many times both in the manufacturing plants and shipped to the customer and returned to Guardian Glass plants.

Glass should be installed according to industry standards and according to all applicable building codes in the given jurisdiction. Glass should be washed frequently to remove surface dirt and to protect the glass from staining. Glass staining occurs when the sodium within the glass reacts with moisture in the air. Sodium, when combined with small amounts of water, can create sodium hydroxide, which is corrosive to glass.

Once installed, Guardian Glass products do not consume energy or require maintenance beyond general cleaning to fulfill their estimated service life. At end-of-life, glass is typically landfilled and in some instances recycled.

Further Information

Further information about Guardian Glass products is available at www.guardianglass.com.

LCA: Calculation Rules

Declared Unit

The declared unit is 1 metric ton (1 tonne or 1,000 kg) of flat glass maintained for a period of 30 years. As Guardian's glass has an estimated service life of greater than 30 years, this EPD represents one tonne of glass.

Table 1: Declared unit and conversion to area

Name	Unit	Flat glass
Declared unit	tonne	1
Thickness	mm	4
Area covered by declared unit	m^2	100

System Boundary

The analysis is conducted for a cradle-to-gate system boundary (Figure 2), as mandated by the PCR. Life cycle stages downstream of Guardian Glass facilities—that is, distribution, use, and end-of-life—are not included. Additionally, transportation to waste or scrap facilities is excluded from the system, as are capital goods, infrastructure, and personnel-related activities.

Figure 2: LCA system boundary

- **Material acquisition & pre-processing:** Upstream production of raw materials, including inbound transportation of these materials to Guardian Glass facilities. For secondary materials such as post-consumer cullet, only the inbound transportation of these materials is considered.
- **Production:** The gate-to-gate production of flat glass products at Guardian Glass facilities—specifically, the transformation of the raw materials to the finished product.
- **Packaging / storage:** Packaging of the product, including production of packaging materials, and on-site storage of the product after it is taken off the production line but before it leaves the facility for delivery to a fabricator or end user.

Estimates and Assumptions

Due to limitations in data availability, assumptions were made in allocating important manufacturing inputs and outputs including process materials, natural gas, and facility emissions. The allocation approaches taken may therefore overestimate the environmental burden for uncoated glass production.

Additionally, the “average“ glass pane used in modeling is a calculated average pane thickness and area and does not represent a specific product manufactured by Guardian Glass.

Cut-off Criteria

No cut-off criteria were applied within this study. 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. In cases where no matching life cycle inventories were available to represent a flow (e.g., the upstream production of a specific material), proxy data were applied based on conservative assumptions regarding environmental impacts.

Background Data

Regional and national averages for fuel inputs, electricity grid mixes, materials, transportation, and disposal methods were obtained from the GaBi 2017 database. Documentation for all GaBi datasets can be found at www.gabi-software.com/international/databases/gabi-databases/.

Data Quality

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

Data included first-hand company manufacturing data in combination with consistent background LCI information from the GaBi 2017 databases.

Period under Review

The data are representative of production at Guardian Glass North America float plants for the 2016 calendar year.

Allocation

Where manufacturing inputs, such as electricity use, were not sub-metered, they were allocated by mass, area, or by expert judgement. For recycled materials, the cut-off allocation approach (also known as the recycled content method) was used.

LCA: Results

Materials and energy consumed per declared unit are presented in Table 2 for one declared unit of flat glass. The lower heating value (LHV) is used for all energy results. Emissions and waste results are shown in Table 3 and Table 4, respectively. Life cycle impact assessment results are shown in Table 5. Human health and eco-toxicity impact categories are not included among reported results due to the uncertainty of their characterization factors.

It shall be noted that impact categories represent potential impacts, i.e., they are approximations of environmental impacts that may occur if the emissions (a) follow the underlying impact pathway and (b) meet the necessary conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the functional unit (relative approach). Life cycle impact assessment results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

Table 2: Energy consumption per declared unit

Parameter	Unit	Flat glass – raw materials	Flat glass – production	Flat glass – total
Non-renewable primary energy demand, fossil	MJ	7.09E+03	1.34E+04	**2.05E+04**
Non-renewable primary energy demand, nuclear	MJ	5.63E+02	3.16E+02	**8.79E+02**
Non-renewable primary energy demand, total	**MJ**	**7.66E+03**	**1.37E+04**	**2.14E+04**
Renewable primary energy demand, solar	MJ	1.03E+02	6.47E+01	**1.67E+02**
Renewable primary energy demand, wind	MJ	1.06E+02	6.54E+01	**1.71E+02**
Renewable primary energy demand, hydro	MJ	1.01E+02	6.67E+01	**1.68E+02**
Renewable primary energy demand, biomass	MJ	0.00E+00	3.07E+00	**3.07E+00**
Renewable primary energy demand, geothermal	MJ	2.17E+01	1.78E+01	**3.95E+01**
Renewable primary energy demand, total	**MJ**	**3.30E+02**	**2.53E+02**	**5.83E+02**
Miscellaneous fuels	MJ	0.00E+00	0.00E+00	**0.00E+00**

Table 3: Emissions and water consumption per declared unit

Parameter	Unit	Flat glass – raw materials	Flat glass – production	Flat glass – total
Emissions to air				
Sulfur oxides (SO_x)	kg	0.00E+00	3.76E-01	**3.76E-01**
Nitrogen oxides (NO_x)	kg	5.54E-01	4.63E+00	**5.19E+00**
Carbon dioxide (CO_2)	kg	4.78E+02	8.93E+02	**1.37E+03**
Carbon monoxide (CO)	kg	2.83E-01	3.35E-01	**6.18E-01**
Volatile organic compounds (VOCs)	kg	9.45E-02	3.27E-01	**4.22E-01**
Iron (Fe)	kg	2.19E-04	1.77E-04	**3.96E-04**
Total particulate matter (PM)	kg	7.27E+00	6.15E-01	**7.89E+00**
Water usage and emissions to water				
Phosphates	kg	9.78E-04	4.36E-04	**1.41E-03**
Nitrates	kg	1.52E-02	1.13E-02	**2.66E-02**
Dioxin	kg	4.53E-18	4.32E-18	**8.86E-18**
Heavy metals				
Arsenic	kg	1.24E-11	2.37E-09	**2.38E-09**
Lead	kg	2.06E-04	3.65E-04	**5.71E-04**
Mercury	kg	1.18E-06	1.73E-06	**2.90E-06**
Cadmium	kg	7.74E-05	1.08E-04	**1.86E-04**
Chromium	kg	1.19E-02	3.02E-02	**4.21E-02**
Water consumption (total input)	m^3	1.72E+03	8.87E+02	**2.61E+03**

Table 4: Wastes per declared unit

Parameter	Unit	Flat glass – raw materials	Flat glass – production	Flat glass – total
Incineration with energy recovery	kg	0.00E+00	0.00E+00	**0.00E+00**
Incineration without energy recovery	kg	0.00E+00	0.00E+00	**0.00E+00**
Landfill (non-hazardous solid waste)	kg	5.26E+01	4.48E+01	**9.75E+01**
Hazardous waste	kg	3.14E-05	6.84E-06	**3.83E-05**
Landfill avoidance (recycling)	kg	0.00E+00	5.70E+01	**5.70E+01**

Table 5: Life cycle impact assessment results per declared unit

Parameter	Unit	Flat glass – raw materials	Flat glass – production	Flat glass – total
TRACI 2.1				
Global warming potential – 100 years	kg CO_2 eq.	5.07E+02	9.48E+02	**1.45E+03**
Acidification potential	kg SO_2 eq.	1.24E+00	4.60E+00	**5.84E+00**
Eutrophication potential	kg N eq.	6.35E-02	2.29E-01	**2.92E-01**
Stratospheric ozone layer depletion potential	kg CFC-11 eq.	6.72E-08	3.77E-08	**1.05E-07**
Photochemical ozone creation potential	kg O_3 eq.	1.93E+01	1.16E+02	**1.35E+02**
ReCiPe 2008				
Mineral resource depletion potential	kg Fe eq.	9.69E+00	5.63E+00	**1.53E+01**

LCA: Interpretation

The analysis results represent the cradle-to-gate environmental performance of both uncoated and processed glass products. For a better understanding of the results and impact drivers for the production of uncoated glass, the environmental performance is further broken down in Figure 3 as follows:

- **Composition 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 for use in the furnace
- **Inbound transport –** ship, rail, and truck transport of raw materials to the manufacturing facilities
- **Direct emissions –** emissions reported by facilities (or calculated as necessary)
- **Miscellaneous –** impacts associated with manufacturing waste, packaging materials, water usage, and onsite transport

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, likely from natural gas combustion. Global warming potential is driven primarily by CO_2 emissions associated with natural soda and silica production, electricity consumption, natural gas production and combustion, as well as CO_2 emissions from melting batch materials. Ozone depletion potential is primarily driven by electricity consumption, specifically from the nuclear power in the US electricity grid, both on the facility level as well as in raw materials production.

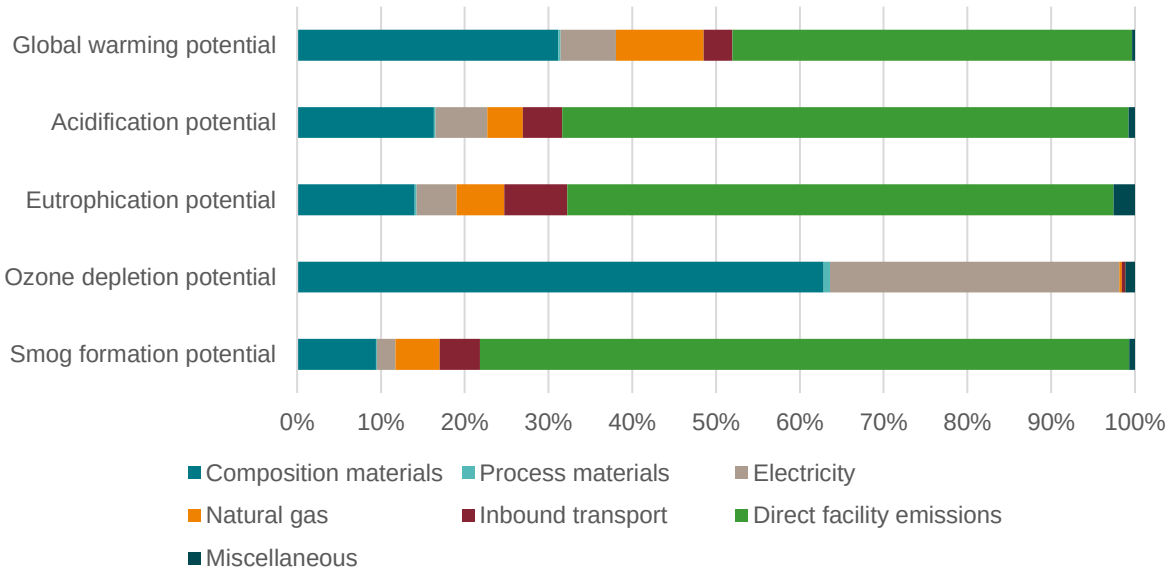


Figure 3: Relative contributions of manufacturing inputs and outputs for uncoated glass production (TRACI 2.1)

Additional Environmental Information

Guardian Glass is committed to being a good corporate citizen to its employees, customers, communities and the environment. Guardian Industries Sustainability Vision guides the company's actions to assist in meeting this commitment:

> *Guardian creates long-term value for society by using resources more efficiently; protecting the environment and the safety and health of our workers and others; consistently applying good science; and employing Market Based Management®. Together these contribute to our overall quality of life.*

In alignment with the company's Sustainability Vision, Guardian Glass actively seeks to minimize waste and improve the environmental, health and safety aspects of its products and processes. Guardian Glass offers competitive products that meet the needs of its customers and improve people's lives using as few resources as necessary.

Guardian's commitment to integrity includes, among other things, an expectation that its suppliers conduct their activities in compliance with all applicable laws. Guardian Glass is committed to sourcing in a socially responsible manner and avoids knowingly using goods, services or raw materials such as tin, tungsten, tantalum or gold (Conflict Minerals) sourced in a way that supports or funds inhumane treatment.

The Guardian Glass Sustainability Calculator can help design professionals evaluate and document the environmental performance of Guardian glass products during the project design phase. The Sustainability Calculator is part of the company's Glass Analytics suite of engineering and analytic tools for glass. These online tools offer a comprehensive suite of engineering and analytical reports that demonstrate the advantages of high performance glass in buildings.

In summary, Guardian Glass has initiated responsible policies and practices to ensure sustainability is embedded into the company's culture and business decisions. Through responsible practices in the areas of environmental management and health and safety, the company's goal is to reduce environmental impacts for communities and create an exceptional workplace for its employees.

References

ASTM C 1036: Standard Specification for Flat Glass

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Contact Information

Study Commissioner

Guardian Glass
2300 Harmon Road
Auburn Hills, MI 48306
+1 (248) 340-1800
info@guardianglass.com
www.guardianglass.com

LCA Practitioner

thinkstep, Inc.
170 Milk St, 3rd floor
Boston, MA 02109
+1 (617) 247-4477
info@thinkstep.com
www.thinkstep.com