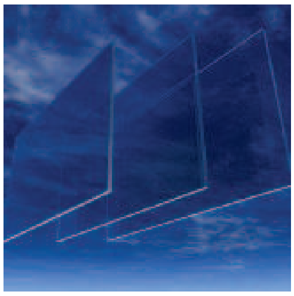
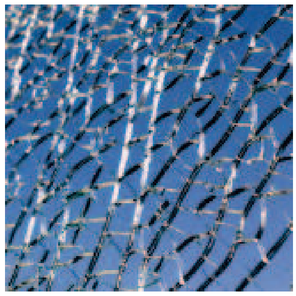
EPD Flat glass, toughened safety glass and laminated safety glass

Environmental **P**roduct **D**eclaration
in accordance with DIN EN ISO 14025 and EN 15804

Flat glass, toughened safety glass and laminated safety glass

Pilkington Deutschland AG





Declaration code
M-EPD-FEV-GB-001017

May 2012

Note: This EPD was created on the basis of the sample EPD FSG/TSG/LSG

Environmental Product Declaration in accordance with ISO 14025 and EN 15804 Summary

ROSENHEIM

Flat glass, toughened safety glass and laminated safety glass

Programme operator	**ift Rosenheim GmbH** Theodor-Gietl-Strasse 7-9 D-83026 Rosenheim
Holder of the declaration	**Pilkington Deutschland AG** Hegestrasse 45966 Gladbeck
Declaration code	M-EPD-FEV-GB-001017
Designation of declared product	Flat glass, toughened safety glass and laminated safety glass
Scope	Flat glass (FG), toughened safety glass (TSG) and laminated safety glass (LSG) for processing into insulating glass units and for use as glass for building (in the building envelope and in the upgrade of construction works).

LCA results per m² and 1 mm of flat glass	Manufacture	End-of-life
Primary energy – non-renewable ($PE_{n\ renw}$) in MJ	44,3	-18,6
Primary energy – renewable (PE_{renw}) in MJ	0,95	-0,18
Global warming potential (GWP 100) in kg CO2 equiv.	2,67	-1,39
Ozone depletion potential (ODP) in kg R11 equiv.	$1{,}84 \times 10^{-8}$	$-3{,}65 \times 10^{-9}$
Acidification potential (AP) in kg SO_2 equiv.	0,023	-0,014
Eutrophication potential (EP) in kg PO_4^{3-} equiv.	$2{,}52 \times 10^{-3}$	-0,001
Photochemical ozone creation potential (POCP) in kg C_2H_4 equiv.	$1{,}37 \times 10^{-3}$	0,000
Abiotic resources depletion potential (elements) ($ADP_{el.}$) in kg Sb equiv.	$1{,}33 \times 10^{-5}$	$-1{,}23 \times 10^{-5}$
Abiotic resources depletion potential (fossil) (ADP_{fos}) in MJ	38,55	-14,01
Water consumption in m³	1,219	-0,36

Basis

- ISO 14025:2006
- EN 15804:2012

Allgemeiner Leitfaden zur Erstellung von Typ III Umweltproduktdeklarationen (Guidance on preparing Type III Environmental Product Declarations).

This Declaration is based on the PCR Document "Flachglas im Bauwesen" (Glass in Building) PCR-FG-1.1 : 2011

Validity

This verified Environmental Product Declaration applies solely to the specified products and is valid for a period of 5 years from the date of issue. The declaration holder assumes full liability for the underlying data, certificates and verifications.

Date created:
01 May 2012

Date of issue:
15 November 2013

Next revision:
01 May 2017

LCA basis

The LCA was prepared in accordance with EN ISO 14040 and EN ISO 14044. The base data include both data collected at various companies and generic data from the "GaBi 4.4" database. LCA calculations were based on the "cradle to grave" life cycle.

The LCA was prepared by PE INTERNATIONAL AG

Basis:
This EPD was prepared on the basis of a model EPD

Notes on publication

The "Conditions and Guidance on the Use of **ift** Test Documents" apply.

Environmental Product Declaration in accordance with ISO 14025 and EN 15804 Summary

Flat glass, toughened safety glass and laminated safety glass

LCA results per m² and 1 mm		Toughened safety glass		Laminated safety glass	
		Manufacture	End-of-life	Manufacture	End-of-life
Primary energy – non-renewable ($PE_{n\ renw}$) in MJ		62,20	-14,72	80,68	-11,19
Primary energy – renewable (PE_{renw}) in MJ		3,76	-0,21	6,18	0,99
Global warming potential (GWP 100) in kg CO2 equiv.		3,65	-1,17	5,42	-1,19
Ozone depletion potential (ODP) in kg R11 equiv.		$7{,}77 \times 10^{-8}$	-4×10^{-9}	$1{,}38 \times 10^{-7}$	$4{,}89 \times 10^{-9}$
Acidification potential (AP) in kg SO_2 equiv.		0,029	-0,015	0,036	-0,015
Eutrophication potential (EP) in kg PO_4^{3-} equiv.		0,003	-0,001	0,003	-0,001
Photochemical ozone creation potential (POCP) in kg C_2H_4 equiv.		0,002	0,000	0,002	0,000
Abiotic resources depletion potential (elements) ($ADP_{el.}$) in kg Sb equiv.		$1{,}37 \times 10^{-5}$	$-7{,}05 \times 10^{-7}$	$1{,}4 \times 10^{-5}$	$-4{,}96 \times 10^{-7}$
Abiotic resources depletion potential (fossil) (ADP_{fos}) in MJ		49,80	-11,79	61,69	-8,56
Water consumption in m³		5,68	-1,08	9,42	-0,6

Ulrich Sieberath

Signature of Director of Institute, ift Rosenheim GmbH

Patrick Wortner

Signature of Verifier

Environmental Product Declaration in accordance with ISO 14025 and EN 15804 Detailed version

ROSENHEIM

Flat glass, toughened safety glass and laminated safety glass

1 Product definition

Product definition

This EPD applies to:

Flat glass, toughened safety glass and laminated safety glass.

The LCA was prepared using the declared unit:

1 m² and 1 mm glass thickness

The declared unit relates to the product and end-of-life stages of 1 m² area and 1 mm thickness of flat glass, toughened safety glass (TSG) or laminated safety glass (LSG).

Product description:

"Flat glass" (FG) refers to both uncoated and coated float glass. Float glass is a clear, flat soda lime silicate glass with parallel, fire-polished surfaces, in some cases bearing metal-oxide-based coatings to modify the radiation (thermal insulation and/or solar control) properties of the glass.

Toughened safety glass (TSG) consists of a single pane that has been specially heat-treated to give the glass increased impact resistance. If the glass breaks under exposure to a high load, it disintegrates into very small fragments with no sharp edges.

Laminated safety glass (LSG) consists of at least two glass panes lying one on top of the other, with one or several layers of a tear-resistant, toughened film, usually polyvinyl butyral (PVB), positioned between the panes.

Cutting/characteristics: Flat glass is generally supplied in stock sizes of 600 x 321 cm. It is cut and processed into toughened safety glass or laminated safety glass on a project-specific basis.

Product standards:

- Flat glass: EN 572
- Toughened safety glass: EN 12150
- Heat strengthened glass: EN 1863
- Laminated safety glass: EN 14449

Application Flat glass, toughened safety glass and laminated safety glass for processing into insulating glass units and for use as glass for building (in the building envelope and in the upgrade of construction works).

Additional information For detailed structural characteristics please refer to the CE marking and to the documents accompanying the product or to the product data sheets.

	Flat glass	Toughened safety glass	Laminated safety glass
Strength	EN 572	EN 12150	EN 14449
Fracture pattern	---	EN 12150	EN 14449
Additional load bearing capacity	No	No	Yes

2 Materials used

2.1 Primary products

Primary products The main components of float glass are the naturally occurring raw materials sand (silicon carbonate, 59%), soda (sodium carbonate, 18%), dolomite (15%), lime (calcium carbonate, 4%), nepheline (3%), and sulphate (1%).

Explanation of materials:

- Flat glass: Soda lime silicate glass
- Coated flat glass: Soda lime silica glass + metal oxides
- TSG: Soda lime silicate glass
- LSG: Soda lime silicate glass + PVB film

2.2 Declarable substances

Declarable substances In accordance with the REACH candidate list, no substances of very high concern are contained.

3 Product stage

Product manufacture Soda lime silicate glass (float glass):

The raw materials are introduced as a mixture into the furnace where they are melted at a temperature of approx. 1560 ℃, generally using gas as an energy resource.

The glass is shaped by distributing the mass of liquid glass over a bath of molten tin. The glass sheet is then cooled evenly and cut to size.

Coated glass is float glass that has been coated with a metal-oxide-based coating using various processes (sputtering, evaporation, pyrolytic processes). The coating is a few atom layers thick.

In the manufacture of TSG, float glass is heated to its transition temperature (min.

640 °C) and then rapidly cooled. This causes the surfaces of the glass to cool and contract faster than the remaining material. This creates additional compressive strength in the surfaces that makes the resulting glass tougher.

For the manufacture of LSG, a PVB film is placed between the panes of glass and these are pressed together in an autoclave under the action of heat and pressure.

The manufacturing processes described are applicable to all manufacturing sites of all manufacturers in Europe, because no production processes are used for the manufacture of FG, TSG and LSG that differ significantly from the above.

4 Construction stage

Processing recommendations, installation

Flat glass (i.e. uncoated and, in some cases, coated float glass) can be processed into toughened safety glass, laminated safety glass, and insulating glass units. It can also be used separately; depending on the application, other processes such as cutting, polishing or drilling may be applied.

Toughened safety glass can be processed into laminated safety glass and insulating glass units. It can also be used separately; depending on the application, other processes such as cutting, polishing or drilling may be applied prior to the thermal toughening process.

Laminated safety glass can be processed into insulating glass units. It can also be used separately; depending on the application, other processes such as cutting, polishing or drilling may be applied.

5 Use stage

Cause/effect relationships Man - Environment

No further emissions to water and soil are known of. The emissions to air are within the official limits. Sound emissions do not exceed the statutory limits.

Due to the wide range of possible applications and designs, the use stage is not taken into account in the calculation.

Service life

If used according to their intended use, flat glass, TSG and LSG can be expected to have a service life of more than 50 years (as per BBSR [German Federal Institute for Research on Building, Urban Affairs and Spatial Development] table "Nutzungsdauer von Bauteilen" [service life of building components]).

6 End-of-life stage

Possible end-of-life stages

FG, LSG and TSG are not specifically designed for reuse, although reuse is by all means possible.

Flat glass can be sorted into its original pure components and reintroduced into the manufacturing process.

Offcuts from glass cutting can be sorted into their original pure components and reintroduced into the float glass process (as per VDI 2243).

90% of flat glass, TSG and LSG is collected and recycled (as per VDI 2243), for example for the manufacture of container glass, insulating wool, sandpaper or glass bricks.

All production waste generated during manufacture is internally recycled.

Disposal routes

Approximately 10% of the products are disposed of at a construction waste dump.

Waste codes:

- 170202 for glass from construction and demolition waste
- 170902 for insulating glass units containing PCBs

7 Life Cycle Assessment (LCA)

Environmental product declarations are based on life cycle analyses (LCAs) which use material and energy flows for the calculation and subsequent representation of environmental impacts.

As the basis for this, an LCA was prepared for flat glass, toughened safety glass and laminated safety glass by PE INTERNATIONAL AG. The LCA was developed in accordance with EN 15804 and the requirements set out by the international standards EN ISO 14040, EN ISO 14044, ISO 21930 and ISO 14025.

The LCA is representative of the products presented in the Declaration and the specified reference period.

7.1 Definition of goal and scope

Goal

The goal of the LCA is to demonstrate the environmental impacts of FG, TSG and LSG. As set out by EN 15804 the environmental impacts covered by the Environmental Product Declaration for flat glass, toughened safety glass and laminated safety glass are presented in the form of basic information. The specified environmental impacts are as follows:

- Primary Energy Demand (PED – renewable and non-renewable)
- Global Warming Potential (GWP)
- Acidification Potential (AP)
- Ozone Depletion Potential (ODP)
- Eutrophication Potential (EP)
- Photochemical Ozone Creation Potential (POCP)
- Abiotic Deplation Potential Elements ($ADP_{element}$)
- Abiotic Deplation Potential Fossil (ADP_{fossil})

These are specified for the declared products for the product and end-of-life stages. Apart from these no other environmental impacts have been specified/presented.

Data quality and data availability

The life cycle of the glass was modelled using the sustainability software tool "GaBi 4" for the development of Life Cycle Assessments. All relevant background datasets for the production of FG, TSG and LSG are taken from the database of the software tool "GaBi 4".

The age of the LCA background data is less than eight years.

The production-specific data for flat glass manufacture are taken from data collected at various typical manufacturer plants. The average values determined are based on the volumes produced by the plants.

For the manufacture of TSG and LSG, typical industry data were collected on the basis of an annual average (2009) for plants of members of the Bundesverband Flachglas e.V. (German Flat Glass Association).

Geographical and time-related system boundaries

The base data for FG manufacture consist of data collected in 2005, corresponding to current production. The data for the manufacture of TSG and LSG are based on the year 2010. The quantity data for the raw materials, energy and ancillary materials used are annual averages. Data were additionally collected by the **ift** Rosenheim in 2012 in order to verify representativeness.

The European electricity mix was used as the basis for energy consumed, with 2008 as the reference year.

Raw materials are modelled using generic data and include average transport distance data.

Scope and system boundaries

The system boundaries refer to all process steps for the manufacture of the glass, from the extraction of the raw materials to the dispatch of the product, ready for shipment, from the production gate.

Due to the wide range of possible applications and designs, the use stage is not included in the calculation.

A scenario is used to offset the recycling against the manufacture of container glass. Transportation associated with the end-of-life stage is likewise included. The end-of-life scenario of the glass includes collection and recycling into container glass (including benefits for a lower use of primary energy in manufacture due to the use of secondary materials, and material batch benefits).

Cut-off criteria

All operating data collected, i.e. all raw materials used by composition, the electrical energy consumed, internal consumption of ancillary materials, all production waste which can be directly attributed to the product, and all available emissions data from the plants, were included in the LCA.

Building sections/parts of facilities that are not relevant to the manufacture of the product were excluded.

It can be assumed that the total of negligible processes per life cycle stage does not exceed 5 percent. The life cycle calculation also includes material and energy flows that account for less than 1 percent.

7.2 Inventory analysis

Goal

All material and energy flows are described below. The processes covered are presented as input and output parameters and refer to the declared/functional units.

The models of the unit processes used for the LCA have been documented in a transparent manner.

Life cycle stages

Product stage A1-A3 and end-of-life stage C1-C4 and D are included.

Benefits

Deductions are made for the recycling of the glass into container glass, using equivalence processes which were also used in the product stage (for sand, soda, powdered limestone).

The use of secondary materials reduces the energy consumption in the manufacturing stage. Account is taken of this reduction using the equivalence processes DE: Strom (DE: electricity) and DE: Thermische Energie aus Erdgas (DE: thermal energy from natural gas) (both GaBi 2009).

The benefits for the recycled glass are calculated on the basis of the corresponding primary production.

It is not envisaged that these products will be thermally recycled, hence no benefits are derived from thermal recycling.

Allocation procedures

Allocation of co-products

Allocations do not need to be performed for product manufacture.

Allocations for reuse and recycling

Allocations for the use of recycled materials/secondary raw materials can be found in the GaBi database documentation.

Allocations based on life cycle boundaries

Use of recycled materials in the product stage was based on the current market-specific situation. In parallel to this, a recycling potential was taken into consideration which reflects the economic value of the product after recycling (recyclate). The system boundary set for the recycled material refers to collection.

Secondary materials

Secondary materials were included in the benefits.

- Open loop (waste recycled into new products)

Inputs

Energy:

The electricity mix is based on "Strommix Europa" (European electricity mix).
Gas is based on "Erdgas Europa" (European natural gas).

Water:

Around 11 l of water are required over the life cycle of 1 m² of FG (1 mm), 19 l over the life cycle of TSG, and 22 l of water for LSG, including upstream processes.

Primary energy:

A quantitative evaluation of the primary energy consumption for the individual sub-systems in the manufacture of 1 m² of various glass types of 1 mm thickness is presented below.

Flat glass					
Analysis parameter	Unit/m²	Manufacture	Raw materials incl. upstream processes	Transport	Total (cradle-to-gate)
PE, non-renewable	[MJ]	34,17	8,92	1,21	44,3
PE, renewable	[MJ]	0,86	0,08	0,01	0,95
Toughened safety glass					
Analysis parameter	Unit/m²	Manufacture	Raw materials incl. upstream processes	Transport	Total (cradle-to-gate)
PE, non-renewable	[MJ]	52,07	8,92	1,21	62,2
PE, renewable	[MJ]	3,67	0,08	0,01	3,76
Laminated safety glass					
Analysis parameter	Unit/m²	Production	Raw materials incl. upstream processes	Transport	Total (cradle-to-gate)
PE, non-renewable	[MJ]	61,31	8,52	1,16	80,62
PE, renewable	[MJ]	5,91	0,07	0,01	6,18

55% of the primary energy used in the manufacture of flat glass is thermal energy from the natural gas and heating oil required for the production of FG in the plant. A further 20% is due to the process upstream of sodium carbonate production and a further 16% to the processes upstream of electricity provision.

Some 45% of the electricity used in the manufacture of TSG is due to the toughening process, while the remaining 55% is due to the processes upstream of FG production.

The bulk of the primary energy consumed in the manufacture of LSG is used in the production of the basic glass.

Life cycle

A quantitative evaluation of primary energy consumption over the life cycle of 1 m² of FG, TSG and LSG is presented in the tables below.

Analysis parameter	Unit/m²	Manufacture	End-of-life	Total
PE, non-renewable	[MJ]	44,3	-18,6	25,7
PE, renewable	[MJ]	0,95	-0,18	0,77

Non-renewable primary energy consumption in the manufacture of FG can be reduced by around 43% due to the recycling potential of FG in its end-of-life stage.

Analysis parameter	Unit/m²	Manufacture	End-of-life	Total
PE, non-renewable	[MJ]	62,20	-14,72	47,48
PE, renewable	[MJ]	3,76	-0,21	3,55

Non-renewable primary energy consumption in the manufacture of TSG can be reduced by around 24% due to the recycling potential of TSG in its end-of-life stage.

Analysis parameter	Unit/m²	Manufacture	End-of-life	Total
PE, non-renewable	[MJ]	80,68	-11,19	69,49
PE, renewable	[MJ]	6,18	0,99	5,19

Non-renewable primary energy consumption in the manufacture of LSG can be reduced by around 14% due to the recycling potential of LSG in its end-of-life stage.

The following graph shows primary energy consumption over the life cycles of the various glass types.

From a more detailed evaluation of the non-renewable primary energy consumption in the manufacture of 1 m² of FG (1 mm) it can be seen that natural gas is a significant primary energy source in the manufacture of this product. Natural gas is used to a significant extent in flat glass production.

The share of uranium is exclusively due to the share of nuclear energy in the electricity mix.

<u>Raw materials/primary products:</u>

Non-renewable material resources		FG		TSG		LSG	
Total	kg	7.73	100%	18.49	100%	19.4	100%
Soil	kg	0.65	8%	0.65	4%	0.62	3%
Waste rock	kg	3.17	41%	13.87	75%	14.71	77%
Siliceous sand	kg	1.63	21%	1.63	9%	1.56	8%
Dolomite	kg	0.46	6%	0.46	2%	0.44	2%
Limestone	kg	1.00	13%	1.04	6%	1.00	5%
Sodium chloride	kg	0.80	10%	0.80	4%	0.76	4%

The main non-renewable material resources consumed are siliceous sand and waste rock.

The table shows the proportions of these material resources as a share of total non-renewable material resources consumed, including upstream processes.

Of these, sand, dolomite and limestone are direct ingredients in the manufacture of flat glass. Sodium chloride is required for the production of sodium carbonate, which in turn in an ingredient in the manufacture of flat glass.

Waste rock is the commercially worthless mass of stone obtained during the mining of ores and energy resources such as coal, etc.

The material resource "Soil" is produced in particular in the excavation and extraction of raw materials for energy generation, and refers to the mass of soil material moved.

Outputs

The LCA includes the production-relevant outputs per m² glass area given below:

Waste:

See 7.3 (Impact assessment).

7.3 Impact assessment

Goal

Impact assessment covers inputs and outputs. The impact categories applied are set out below:

Impact categories

Manufacture

A quantitative evaluation of the environmental impacts of the individual subsystems in the manufacture of 1m² of FG, TSG and LSG with a thickness of 1 mm is presented below.

Flat glass					
Analysis parameter	Unit/m²	Manufacture	Raw materials incl. upstream processes	Transport	Total (cradle-to-gate)
GWP	[kg CO_2 equiv.]	1,8	0,79	0,08	2,67
ODP	[kg R11 equiv.]	$2{,}97 \times 10^{-9}$	$1{,}42 \times 10^{-8}$	$1{,}23 \times 10^{-9}$	$1{,}84 \times 10^{-8}$
AP	[kg SO_2 equiv.]	0,0193	$3{,}63 \times 10^{-3}$	$4{,}48 \times 10^{-4}$	$2{,}34 \times 10^{-2}$
EP	[kg PO_4^{3-} equiv.]	$1{,}83 \times 10^{-3}$	$6{,}01 \times 10^{-4}$	$9{,}02 \times 10^{-5}$	$2{,}52 \times 10^{-3}$
POCP	[kg C_2H_4 equiv.]	$1{,}08 \times 10^{-3}$	$2{,}42 \times 10^{-4}$	$4{,}51 \times 10^{-5}$	$1{,}37 \times 10^{-3}$

Toughened safety glass					
Analysis parameter	Unit/m²	Manufacture	Raw materials incl. upstream processes	Transport	Total (cradle-to-gate)
GWP	[kg CO_2 equiv.]	2,78	0,79	0,08	3,65
ODP	[kg R11 equiv.]	$6{,}23 \times 10^{-8}$	$1{,}42\ 10^{-8}$	$1{,}23 \times 10^{-9}$	$7{,}77 \times 10^{-8}$
AP	[kg SO_2 equiv.]	0,024	$3{,}63 \times 10^{-3}$	$4{,}48 \times 10^{-4}$	$2{,}85 \times 10^{-2}$
EP	[kg PO_4^{3-} equiv.]	$2{,}09 \times 10^{-3}$	$6{,}01 \times 10^{-4}$	$9{,}02 \times 10^{-5}$	$2{,}78 \times 10^{-3}$
POCP	[kg C_2H_4 equiv.]	$9{,}67 \times 10^{-4}$	$2{,}42 \times 10^{-4}$	$4{,}51 \times 10^{-4}$	$1{,}66 \times 10^{-3}$

Laminated safety glass					
Analysis parameter	Unit/m²	Manufacture	Raw materials incl. upstream processes	Transport	Total (cradle-to-gate)
GWP	[kg CO_2 equiv.]	4,58	0,76	0,08	5,42
ODP	[kg R11 equiv.]	1,23E-07	1,35E-08	1,17E-09	1,38E-07
AP	[kg SO_2 equiv.]	0,033	3,47E-03	4,28E-04	0,037
EP	[kg PO_4^{3-} equiv.]	2,44E-03	5,74E-04	8,62E-05	3,1E-03
POCP	[kg C_2H_4 equiv.]	2,13E-03	2,32E-04	4,31E-05	2,4E-03

The prime environmental impacts in the manufacture of flat glass are due to the consumption of energy resources in the melting process and the associated emissions at plant level.

In the manufacture of TSG the main environmental impacts are due to electricity consumption in the thermal toughening process. The same applies in the manufacture of LSG.

By way of example, the tables show the environmental impacts resulting from the manufacture of 1 m² of the various glass types for selected impact categories.

Global warming potential is due primarily to carbon dioxide emissions. Flat glass manufacture is responsible for some two-thirds of GWP in the manufacture of TSG.

This is due in particular to the consumption of energy resources in the melting process and the associated emissions. For LSG, the manufacture of the TSG in turn accounts for around 90% of GWP. Emissions in the product stage are due in particular to processes upstream of electricity provision.

Ozone depletion potential is due primarily to the electricity mix, and to the electricity consumed directly in the plant in the manufacture of TSG and LSG, and electricity consumed in the processes upstream of flat glass manufacture.

Acidification potential is primarily due to sulphur dioxide emissions and nitrogen oxides generated by the manufacture of the flat glass. This is due in particular to the consumption of energy resources in the melting process and the associated emissions. Flat glass production is responsible for some 89% of the nitrogen oxides contributing to AP, and around 64% of the sulphur dioxides contributing to AP. For LSG, the manufacture of the TSG in turn accounts for some 97% of the nitrogen oxides contributing to the AP of the LSG, and around 91% of the sulphur dioxides contributing to its AP. Emissions from manufacture are due in particular to processes upstream of electricity provision.

Eutrophication potential is primarily due to nitrogen oxides resulting from the manufacture of the flat glass. This is due in particular to the consumption of energy resources in the melting process and the associated emissions. The manufacture of the flat glass is responsible for some 50% of the nitrogen oxides contributing to the EP of the TSG. For LSG, the production of the TSG in turn accounts for some 97% of the nitrogen oxides contributing to the EP of the LSG. Emissions from manufacture are due in particular to processes upstream of electricity provision.

It is primarily sulphur dioxide emissions, nitrogen oxides and NMVOC emissions from the manufacture of the flat glass that are responsible for the photochemical ozone creation potential.

This is due in particular to the consumption of energy resources in the melting process and the associated emissions. The manufacture of the flat glass is responsible for some 89% of the nitrogen oxides contributing to the POCP of the TSG, and around 64% of the sulphur dioxides contributing to its POCP. For LSG, the manufacture of the TSG in turn accounts for 97% of the nitrogen oxides contributing to the POCP of the LSG, and around 91% of the sulphur dioxides contributing to its POCP. Emissions from manufacture are due in particular to processes upstream of electricity provision.

Generally, the influences of transportation and of the film in LSG have a low significance.

Life cycle

A quantitative evaluation of the environmental impacts of the manufacture and end-of-life of 1 m² of the various glass types is presented in the table below.

Analysis parameter	Unit/m²	Manu-facture	End-of-life	Total
GWP	[kg CO_2 equiv.]	2,67	-1,39	1,28
ODP	[kg R11 equiv.]	1,84 x 10-8	-3,65 x 10-9	1,5 x 10-8
AP	[kg SO_2 equiv.]	0,023	-0,014	0,009
EP	[kg PO_4^{3-} equiv.]	2,52 x 10-3	-0,001	1,52 x 10-3
POCP	[kg C_2H_4 equiv.]	1,37 x 10-3	0,000	1,37 x 10-3
$ADP_{el.}$	[kg Sb-Äqv.]	1,33 x 10-5	-1,23 x 10-5	1 x 10-6
ADP_{fos}	[MJ]	38,55	-14,01	24,54
Wasserver-brauch	m³	1,219	-0,36	0,859

The GWP for the manufacture of FG can be reduced by around 52% due to the re-cycling potential of FG in its end-of-life stage.

Analysis parameter	Unit/m²	Manu-facture	End-of-life	Total
GWP	[kg CO_2-Äqv.]	3,65	-1,17	2,48
ODP	[kg R11-Äqv.]	7,77 x 10-8	-4 x 10-9	7,4 x 10-8
AP	[kg SO_2-Äqv.]	0,029	-0,015	0,014
EP	[kg PO_4^{3-} -Äqv.]	0,003	-0,001	0,002
POCP	[kg C_2H_4-Äqv.]	0,002	0,000	0,002
$ADP_{el.}$	[kg Sb-Äqv.]	1,37 x 10-5	-7,05 x 10-7	1,29 x 10-5
ADP_{fos}	[MJ]	49,80	-11,79	38,01
Wasserver-brauch	m³	5,68	-1,08	4,6

recycling potential of TSG in its end-of-life stage.

Analysis parameter	Unit/m²	Manu-facture	End-of-life	Total
GWP	[kg CO_2-Äqv.]	5,42	-1,19	4,23
ODP	[kg R11-Äqv.]	1,38 x 10-7	4,89 x 10-9	1,33 x 10-7
AP	[kg SO_2-Äqv.]	0,036	-0,015	0,021
EP	[kg PO_4^{3-} -Äqv.]	0,003	-0,001	0,002
POCP	[kg C_2H_4-Äqv.]	0,002	0,000	0,002
$ADP_{el.}$	[kg Sb-Äqv.]	1,4 x 10-5	-4,96 x 10-7	1,35 x 10-5
ADP_{fos}	[MJ]	61,69	-8,56	53,13
Wasserver-brauch	m³	9,42	-0,6	8,82

The GWP for the manufacture of LSG can be reduced by around 8% due to the recycling potential of LSG in its end-of-life stage.

The waste generated is evaluated separately for each of the three main fractions, namely stockpiles (including residues from ore dressing), municipal waste (including domestic and commercial waste), and radioactive waste.

Stockpiles make up the largest share of the waste generated by manufacture. Stockpiles are generated primarily by the processes upstream of electricity generation, particularly the extraction of energy resources. For the manufacture of TSG and LSG, these are primarily energy resources for electricity generation. Stockpiles generated in the manufacture of flat glass are produced mainly by the processes upstream of sodium carbonate production.

Municipal waste is generated particularly by the processes upstream of sodium carbonate production. Sodium carbonate is required for the manufacture of flat glass, which in turn is a significant process step in the manufacture of TSG and LSG.

Special waste and radioactive waste are classified as "hazardous waste". Special waste is generated mainly in upstream steps. A notable example is slurry from the processes upstream of sodium carbonate production. Radioactive waste is generated exclusively by electricity generation at nuclear power stations.

The following tables show the waste generated over the life cycle of 1 m² and 1 mm thickness of the various glass types investigated.

Flat glass				
Analysis parameter	Unit	Manu-facture	End-of-life	Total
Stockpiles	[kg/m²]	3,49	-2,90	0,59
Trade wastes	[kg/m²]	0,00	-0,00	0,00
Special waste	[kg/m²]	0,00	-0,00	0,00
Radioactive waste	[kg/m²]	0,0008	-0,0002	0,0006

Toughened safety glass				
Analysis parameter	Unit	Manu-facture	End-of-life	Total
Stockpiles	[kg/m²]	7,29	-1,6362	5,6538
Trade wastes	[kg/m²]	0,00	0,00	0,00
Special waste	[kg/m²]	0,00	-0,00	0,00
Radioactive waste	[kg/m²]	0,003	-0,001	0,002
Laminated safety glass				
Analysis parameter	Unit	Manu-facture	End-of-life	Total
Stockpiles	[kg/m²]	10,83	-0,9743	14,06
Trade wastes	[kg/m²]	0,0002	-0,002	0,00
Special waste	[kg/m²]	0,0002	-0,0002	0,00
Radioactive waste	[kg/m²]	0,0051	0,0002	0,0052

7.4 Interpretation, LCA presentation and critical verification

Interpretation

All relevant and necessary items as per EN ISO 14040 and EN ISO 14044 were included in the LCA. It can therefore be assumed that the LCA is suitable, without restriction, for use in the Environmental Product Declaration for flat glass, toughened safety glass and laminated safety glass.

Report

The LCA report was prepared in accordance with the requirements of EN ISO 14040, EN ISO 14044, EN 15804 and ISO 14025.

The results of the study are not designed to be used for comparative statements intended for publication.

The results and conclusions reported to the target group are complete, correct, without bias and transparent.

The report is not addressed to third parties due to confidential information contained in the report.

Critical verification

The LCA was critically verified by the independent **ift** verifier Patrick Wortner.

8 Validation

Verification of the Environmental Product Declaration is documented in accordance with the **ift** "Richtlinie zur Erstellung von Typ III Umweltproduktdeklarationen" (Guidance on preparing Type III Environmental Product Declarations) in accordance with the requirements set out by ISO 14025.

This Declaration is based on the PCR Document "Flachglas im Bauwesen" (Glass in Building): PCR-FG-1.1 : 2011

Review of the PCR document by the **ift** expert committee in accordance with the CEN standard EN 15804 Independent verification of the Declaration to ISO 14025: ☒ Internal ☐ External Validation of the Declaration: Patrick Wortner

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The EPD document is a result of the research project "Entwicklung von Umweltproduktdeklarationen für transparente Bauelemente – Fenster und Glas – für die Bewertung der Nachhaltigkeit von Gebäuden" (Development of Environmental Product Declarations for transparent components – windows and glass – for evaluating the sustainability of buildings). This project was sponsored by:

"Zukunft Bau" research initiative

German Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) at the German Federal Office for Building and Regional Planning (BBR)

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Notes
This EPD is mainly based on the work and findings of the Institut für Fenstertechnik e.V., Rosenheim (ift Rosenheim) and specifically on the ift-Richtlinie NA-01/1 Allgemeiner Leitfaden zur Erstellung von Typ III Umweltproduktdeklarationen (Guideline NA.01/1 – Guidance on the Preparation of Type III Environmental Product Declarations).
Its basis is the research project "EPDs für transparente Bauelemente" (EPDs for transparent building components) conducted in cooperation with the Bundesverband Flachglas e.V. (German Flat Glass Association), the Fachverband Schloss und Beschlagsindustrie e.V. (Lock and Hardware Industry Association), the Qualitätsverband Kunststofferzeugnisse e.V. (Plastic Products Quality Association) and the Verband Fenster + Fassade (Window + Facade Association). The research bodies involved were PE International AG, the Institute Construction and Environment (IBU), and the **ift** Rosenheim. The project was sponsored by the Zukunft Bau research initiative of the BBSR.

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