

PLEXIGLAS®
Multi-Skin Sheet

Environmental Product Declaration to ISO 14021



1 Summary

Owner of environmental product declaration

Röhm GmbH
Riedbahnstraße 70
64331 Weiterstadt

Date of issue

August 2013

Valid until

Unbefristet

Products examined

PLEXIGLAS® multi-skin sheets

Scope of validity

The Environmental Product Declaration applies to PLEXIGLAS® multi-skin sheets

- PLEXIGLAS® Resist SDP 16/32
- PLEXIGLAS® Alltop SDP 16/64

Unit examined

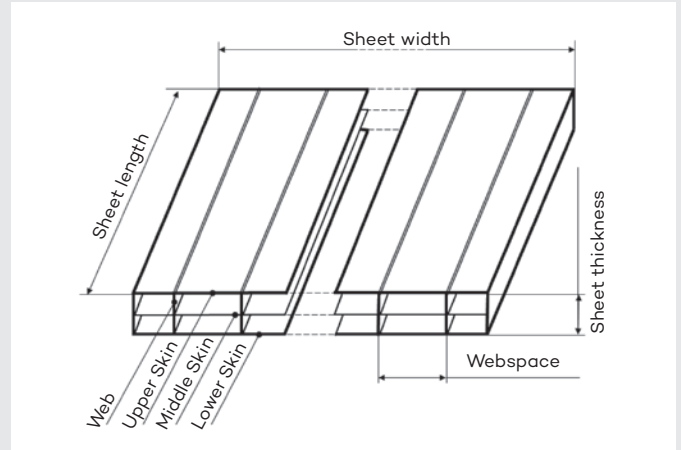
1 m² PLEXIGLAS® multi-skin sheet

2 Product

2.1 Product Description

PLEXIGLAS® multi-skin sheets are flat extruded sheets with enclosed cavities made from clear-transparent or colored polymethyl methacrylate (PMMA or acrylic) produced by Röhm GmbH (registered trademark PLEXIGLAS®). They have two parallel outer skins that are connected with each other by vertical webs. The sheets may contain one or more interior skins in addition to the two exterior skins. The spacing of the skins and webs may differ in different sheet grades.

Depending on the number of interior skins and the position of the vertical webs, a distinction is made between double-skin sheets (SDP), triple-skin sheets (S3P), quadruple-skin sheets (S4P), quintuple-skin sheets (S5P), etc.



PLEXIGLAS® Multi-Skin Sheets, Nomenclature

The multi-skin sheets are manufactured in accordance with EN ISO 12017.

The multi-skin sheets presented in this Environmental Product Declaration, PLEXIGLAS® Alltop SDP 16 and PLEXIGLAS® Resist SDP 16, show the property profile that is typical of PLEXIGLAS®.

Among other things, they possess

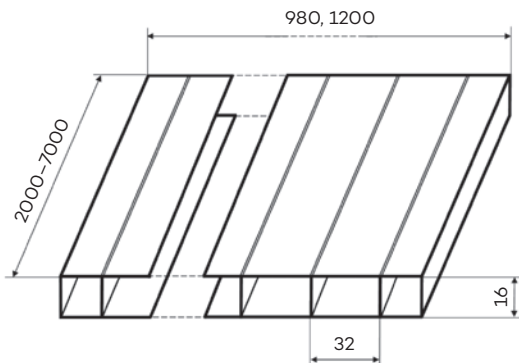
- a crystal-clear appearance
- high light transmission
- extremely high resistance to weathering and UV light

In addition to these typical attributes, they are distinguished by other specific properties.

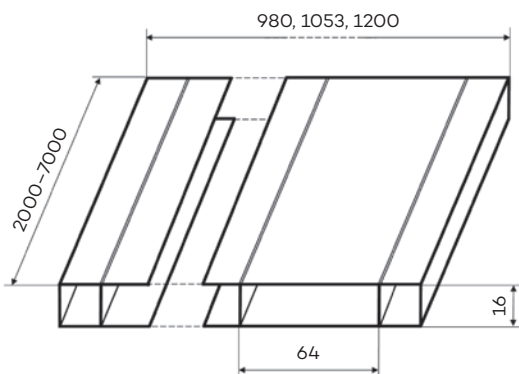
PLEXIGLAS® Resist SDP 16 sheets have a web spacing of 32 mm, are impact-resistant and usually have a water-dispersing and anti-algae coating on one side.

PLEXIGLAS® Alltop SDP 16 sheets have a web spacing of 64 mm, transmit UV light and are equipped with a water-dispersing coating over their entire surface, also inside the cavities, which substantially reduces light loss due to condensation.

PLEXIGLAS® Multi-Skin-Sheet



PLEXIGLAS® Resist SDP 16/32



PLEXIGLAS® Alltop SDP 16/64

2.2 Application

PLEXIGLAS® Resist and PLEXIGLAS® Alltop SDP 16 multi-skin sheets are used both in the business-to-business (B to B) and the business-to-consumer (B to C) areas.

Private users (B to C) use the PLEXIGLAS® multi-skin sheets for example for patio roofs, carport roofs, conservatories, verandas, as glazing material for amateur greenhouses, etc.

Commercial customers (B to B) use the PLEXIGLAS® multi-skin sheets for exterior applications, e.g. glazing material for commercial greenhouses and zoological gardens, skylights, façades, etc.

Other interior applications include store fixtures and exhibition booths, partitions, artworks, lighting applications and similar uses.

The crucial factor in many of these applications is the extremely high resistance to UV light or weathering due to the chemical composition of PLEXIGLAS®.

Owing to this weather resistance, PLEXIGLAS® Resist and Alltop multi-skin sheets show no yellowing for many years, and their very high light transmission remains virtually unchanged (30-year non-yellowing guarantee). PLEXIGLAS® multi-skin sheets can therefore be used for very long periods in exterior applications, and in many cases never need to be exchanged during their entire use.

PLEXIGLAS® Resist multi-skin sheets in particular usually absorb UV light and can therefore be used for roofing to protect against excessive UV radiation and its harmful effects on health.

For applications in greenhouses, zoological gardens and so on, the possible transmission of UV light by PLEXIGLAS® multi-skin sheets is often a decisive feature. This provides plants and animals living beneath roofs made of PLEXIGLAS® multi-skin sheets with almost the same conditions as in nature or in the wild.

These properties offered by PLEXIGLAS® multi-skin sheets are often combined with different heat insulation values, degrees of impact strength and functional coatings, such as water-dispersing No Drop coatings, or biologically neutral, non-toxic coatings that help to prevent the growth of algae.

2.3 Technical Data

	PLEXIGLAS® Alltop SDP 16	PLEXIGLAS® Resist SDP 16
Product photo		
Density PMMA (ISO 1183) [g/cm³]	1,19	1,19
Colors	Clear	Clear, white, gray
Transmission of UV light	Yes	On request
Light transmittance TD65 (DIN 5036) [%]	Up to 91	Up to 86
Total energy transmittance g (DIN EN 410) [%]	Up to 82	Up to 82
U-value [W/m²K]	2,5	2,5
Coefficient of linear thermal expansion α [mm/mK]	0,07	0,09
Possible expansion due to heat and humidity [mm/m]	Approx. 5	Approx. 6
Max. service temperature [°C]	70	70
Weighted sound reduction index [dB]	Approx. 22	Approx. 24

2.4 Marketing/Rules for Application

The multi-skin sheets are manufactured in accordance with EN ISO 12017.
The fire protection requirements depend on the field of application of the multi-skin sheets.

2.5 Condition on delivery

	PLEXIGLAS® Alltop SDP 16	PLEXIGLAS® Resist SDP 16
Thickness [mm]	16	16
Widths [mm]	980, 1053, 1200	980, 1200
Web spacing [mm]	64	32
Delivery lengths [mm]	2000-7000, special lengths available	2000-7000, special lengths available

2.6 Base materials/Extenders

The PLEXIGLAS® grades described here consist of polymethyl methacrylate that may contain up to 20% of other constituents incorporated by polymerization (e.g. acrylate or methacrylate compounds). The basic chemical structure of PLEXIGLAS® contains no substances that are acutely toxic, carcinogenic, mutagenic or teratogenic. It is therefore neither harmful to health nor to the environment.

2.7 Manufacture

PLEXIGLAS® multi-skin sheets are manufactured by extrusion. PLEXIGLAS® pellets are melted in a heated steel barrel and pressed through a forming tool by means of a screw that rotates inside the barrel.

PLEXIGLAS® multi-skin sheets receive their final shape during subsequent calibration. After calibration they are cut to size and stacked on pallets.

2.8 Environmental and Health Aspects during Manufacture

The emissions (vapors) produced during manufacture (extrusion) are extracted and purified by biofilters. No wastewater or waste are produced during normal operation. As far as possible, production wastes are fed back into the production process. The multi-skin sheets are manufactured in accordance with DIN ISO 14001 and with occupational health and safety standard OHSAS 18001.

2.9 Product installation

The multi-skin sheets are usually installed on a load-bearing supporting structure, bearing in mind the relevant snow load and wind pressure. The sides of the sheets are installed in such a way as to allow for expansion and shrinkage, using suitable glazing systems. The corresponding technical regulations apply, in addition to the manufacturer's statements on assembly and fabrication.

2.10 Packaging

The multi-skin sheets are supplied by the manufacturer on wooden pallets. The number of pallets varies depending on sheet length and width between 25 and 45 multi-skin

sheets per pallet. The sheets are then packaged to individual order by distributors or fabricators. The multi-skin sheets are protected on both sides by masking film applied at the factory. To protect the sheets against atmospheric influences, the pallets are covered with protective sheeting at the factory.

2.11 Physical State

Owing to the chemical composition of PLEXIGLAS®, PLEXIGLAS® multi-skin sheets offer extremely high weather resistance. This means there is no need to apply a UV-protective coating.

2.12 Environmental and Health Aspects during Use

From the point of view of Röhm GmbH, the PLEXIGLAS® products described here can be used as a group of plastics in the fields of application in demand on the market in compliance with all the relevant health and safety aspects. Owing to their manufacturing process, the products contain no plasticizers, heavy metal salts or halogens, particularly chlorine. In addition, their basic chemical structure contains no nitrogen compounds or aromatic fractions such as bisphenol A. Additives are required in only very small quantities. Owing to its basic chemical structure, PLEXIGLAS® normally emits no toxic or cancerogenic, mutagenic, teratogenic or otherwise undesirable substances even above the softening temperature (around 100 degrees Celsius).

2.13 Typical service life

The service life of PLEXIGLAS® multi-skin sheets depends on the application. Service periods of up to 35 years are possible, e.g. for patio roofs, and reflect experiential values for the use of multi-skin sheets. In greenhouses, the technology used in the individual greenhouse determines the service life of 30 years (see also section 3.1).

2.14 Unusual influences

Fire

Fire often spreads very rapidly and ignites other flammable materials. These often produce such large amounts of thick smoke that it is very difficult to see within seconds. Exit signs very quickly become obscured. Many materials also develop highly toxic gases. Both of these aspects are

extremely dangerous and can be fatal within a very short time. Various technical publications describe that 80% of all fire deaths are due to smoke gases rather than flames. Fire can never be completely excluded, but it can be influenced by using suitable construction materials.

PLEXIGLAS® burns without hardly any smoke in accordance with DIN 4102. This prevents a loss of visibility due to thick smoke. The smoke gases emitted by PLEXIGLAS® are not acutely toxic as defined by DIN 53436 and are considered harmless as defined by this standard. This makes it possible to reduce the risk of toxic smoke inhalation. The smoke gases emitted by PLEXIGLAS® are non-corrosive in accordance with DIN VDE 0482-267. This makes it possible to reduce the risk of financial damage owing to aggressive smoke gases. Burning PLEXIGLAS® is easy to extinguish. Water is usually sufficient as an extinguishing agent.

Roof glazing made of PLEXIGLAS® opens up by melting in the event of fire and enables smoke and heat to escape. In terms of fire behavior, PLEXIGLAS® is rated in European Class E in line with DIN EN 13501. In Germany, PLEXIGLAS® meets the requirements of construction material class B2, normally flammable, with no burning droplets.

Water

Owing to its chemical composition, PLEXIGLAS® does not react with water.

Mechanical destruction

Owing to their chemical and geometric structure, PLEXIGLAS® multi-skin sheets are extremely resistant to normal mechanical influences during installation and use. However, even PLEXIGLAS® multi-skin sheets can be damaged by unusually strong influences such as severe hailstorms (hail energy > 1 joule).

Owing to the double-skin structure of PLEXIGLAS® multi-skin sheets, holes are usually only produced in the outer skin. Hailstones may penetrate the entire sheet in the event of very severe storms. However, breakage is usually limited to the area of impact, and any fragments produced are only small and are not dangerous. Usually they pose no danger either to people or items of property beneath the glazing. In greenhouses, for example, the crops and soil are not destroyed or contaminated by dangerous slivers of glass. The sheets normally remain in-

side their assembly systems, and can be repaired, sealed or exchanged, depending on the degree of damage.

Greenhouses made with PLEXIGLAS® multi-skin sheets can usually remain in operation even after a severe hailstorm.

2.15 End of Life

PLEXIGLAS® multi-skin sheets can be completely recycled (material recovery). Unlike most other polymers, PMMA can be depolymerized into MMA again by heating. This makes it possible to process the material into PLEXIGLAS® and use it again. It should be noted that no comprehensive collection system has been in place for PLEXIGLAS® as yet. However, there are individual recycling plants that enable large-scale applications in particular to be economically recycled. No toxic emissions are produced during possible waste-to-energy operations.

2.16 Disposal

Disposal is performed either by countrywide disposal companies or via household waste. PLEXIGLAS® multi-skin sheets are not classed as special waste.

2.17 Further Information

You can find further information on PLEXIGLAS® multi-skin sheets at www.plexiglas.de.

3 LCA: Calculation Principles

The life cycle assessments based on the data stated here were performed in accordance with the specifications of standards DIN EN ISO 14040 and 14044. This ensured the conformity of the methods, database and calculations used in all impact categories. In line with the relevant standards, the LCA reports [Hegger 2010] [Evonik 2012] were certified by external experts (critical review).

In line with ISO 14044, the following points of the study were examined:

- Conformity with ISO 14040 and ISO 14044
- Assessment of the applied methods with regard to scientific and technical aspects

- Assessment of the data used
- Assessment of evaluation and interpretation of results, bearing in mind the
- objectives of the study and the known limitations
- Report

In the critical reviews, the following comments were made, among others:

- “The changes made in terms of updates correspond to the state of the art and are explained in a clear and critical way.”
- “The data used, both those of the foreground and background system, are consistent and of high quality.”
- “The final results in all impact categories are plausible and coherent.”

The models used in the life cycle assessments for two production sites of Röhm GmbH were combined for the purpose of drawing up this declaration, and updated to reflect the latest version (July 2013) of the software used by PE International (GaBi 6).

3.1 Declared Unit

This section looks at two utilization scenarios for PLEXIGLAS® multi-skin sheets. Accordingly, two functional units are defined that differ particularly in relation to the service life.

For the present examination, 1 m² PLEXIGLAS® Resist SDP 16 – 32 in 16mm thickness is established as the functional unit, installed as a patio roof. 1 m² PLEXIGLAS® Resist SDP 16 – 32 (d = 16 mm) weighs 4.3 kg. A service life of 35 years is assumed, based on experiential values in the construction industry.

PLEXIGLAS® Alltop SDP 16 – 64 in 16mm thickness was established as the second functional unit, installed as a greenhouse roof. The reference value is 1 m² PLEXIGLAS® Alltop SDP 16 – 64, weighing 5 kg. Here, a service life of 30 years is assumed. The service phase is determined not by the service life of PLEXIGLAS® Alltop SDP 16 – 64, but by the technology used in the greenhouse. After 30 years, this is so outdated that the greenhouse operators dismantle the greenhouses and erect them anew.

3.2 System Boundary

Cradle-to-grave is the system boundary of the systems examined here. To calculate the life cycle assessment, consideration is given to the modules A1 (provision of feedstocks), A2 (transportation of feedstocks to the factory), A3 (production including packaging, provision of energy and production processes), A4 (transportation to the installation site), A5 (installation), B6 (use of energy at the factory), C2 (transportation to disposal site) and D (recycling). All further modules are not relevant to the applications examined here.

The raw materials are examined up to the elementary flows. No consideration is given to the construction of the production lines or the infrastructure required for transportation. Nor is consideration given to the effort involved in developing the product or of the input and output flows for administration. Real data from the production lines, e.g. from the central accounting system, were used for capturing the production data.

3.3 Estimates and Assumptions

There were no assumptions about uncontrolled emissions during manufacture. Such assumptions are therefore not considered here.

An average distance of 500 km is assumed for transportation to the installation site. Packaging produces waste during installation. This is used for energy recovery. The transportation of raw materials and feedstocks to the production sites reflects the actual transports.

Hardly any materials or energy are required for cleaning PLEXIGLAS® multi-skin sheets in the service phase. Emissions during the service phase are therefore ignored.

3.4 Cut-off Rules

Some of the extenders used to produce the feedstock MMA were ignored in the model because they are used in negligible quantities (amounting to less than 0.5% of the mass).

3.5 Background Data

The background data on power supply, feedstocks, transportation and disposal mainly come from PE International's GaBi 6 database and are available as generic data.

The established methodology of the Institute of Environmental Sciences at the University of Leiden (CML), the Netherlands, was used to assess the results of the life cycle inventories, using characterization factors dating from November 2010.

3.6 Data Quality

The average production data were determined over the reference years, if not otherwise available. The feedstock data and (by-) product quantities were taken from the SAP system at the plant sites and are therefore extremely accurate. The feedstock yield may, however, vary in actual operation owing to load changes. Some uncertainties are due to the facility network and feedstocks that are procured externally. The values used here may, however, be considered as secured over the temporal average.

We refer to the documentation in the databases with regard to the cut-off criteria for the background data [GaBi 6 2013].

3.7 Period under Review

The data are based on production data for 2007 and 2011, with updates from 2012. The background data were updated at the time of modeling (GaBi 6, service pack 22, as at: July 2013).

3.8 Allocation

A co-product is produced during production of the feedstock methyl methacrylate. This is not required for further production, but is used in other applications. A value allocation was made in this context. Mass allocation was used for other by-products that are utilized.

With regard to recycled PLEXIGLAS®, it is assumed that recycling prevents emissions during the manufacture of new PMMA.

3.9 Assumptions for Classifying the Results

The following descriptions of other products conventionally available on the market with the same applications as greenhouse glazing and patio roofing are based on the life cycle assessment certified by PE International in line with DIN EN ISO 14040 and 14044 [Hegger 2010] [Evonik 2012] and update to the latest software version (GaBi 6, service pack 22, as at: July 2013).

The data on the service phase per m² PLEXIGLAS® Alltop SDP 16 – 64 in greenhouses refers to actually measured data. This concerns a greenhouse used to cultivate potted orchids in the Netherlands, which was glazed with PLEXIGLAS®. The heat loss is much lower in this case (2.5 W/m²K) as compared with glass (6 W/m²K). This means that at a constant indoor temperature of 27°C, the consumption of natural gas can be reduced from 55 m³/m²a to approx. 30 m³/m²a. In the life cycle analysis performed on the previous glazing, one square meter of single glazing in 4mm thickness and a weight per unit area of 9.96 kg/m² was used as a functional unit. The emission values available in the GaBi 6 database for float glass from Germany were applied to the manufacture of the flat glass sheet. The service life here is limited by the technology used in the greenhouse and also calculated as 30 years. For the further modules (transportation, end-of-life), similar assumptions were made to those for using PLEXIGLAS®. However, here the non-recycled portion is landfilled since it cannot be used for energy recovery.

Classification of the results of the patio roofing with PLEXIGLAS® Resist SDP 16 – 32 is based on the published manufacturer's guarantee for polycarbonate (PC) for identical use as a multi-skin sheet with a typical weight per unit area of 2.8 kg/m². PC multi-skin sheets usually come with a 10-year guarantee, in some cases with a 15-year guarantee. Given an assumed service life of 15 years and an expected service life of the roofing of 35 years, it would need to be replaced twice. The emission values available in the GaBi 6 database for PC pellets from Germany were applied to the manufacture of the polycarbonate sheet. For the further modules (transportation, end-of-life), similar assumptions were made to those for using PLEXIGLAS®.

4 LCA: Scenarios and further technical information

In the scenarios presented here, the dismantled PLEXIGLAS® Resist SDP 16 – 32 sheets are partly recycled (material recovery, 10%) and largely used for energy recovery (90%). In the opposite case, it is assumed for large-scale applications of PLEXIGLAS® Alltop SDP 16 – 64 (such as greenhouse glazing) that 90% of the material is recovered and 10% is converted to energy. Since a large volume of PLEXIGLAS® is used in a coherent and easy-to-dismantle construction in the case of greenhouse glazing, and the recycling company pays for the return the used material in line with its market value, it can be presumed that almost all of the total volume of installed PLEXIGLAS® is recycled. Only the remains of in-

dividual sheets that were destroyed during the life cycle are probably passed on for energy recovery.

Energy recovery (waste-to-energy) results in an electricity credit (Deutscher Mix, 2013) and thermal energy from the German natural gas mix.

Components that are not used for recycling are assumed in this study to be converted to energy in a waste-fed heating and power plant near the site of utilization (50 km away).

Module A5 (installation) takes into account the conversion to energy of the packaging/transport containers. This explains the credits.

5 LCA Results

Statement of System Boundaries (X = Contained in LCA; NDM = Non-declared Module)

Production stage			Construction stage		Service stage					Disposal stage				Credits from disposal stage		
Feedstock supply	Transportation	Manufacture	Transportation to construction site	Installation in the building	Use/Application	Maintenance	Repair	Replacement ¹⁾	Renewal ¹⁾	Use of energy for operating the building	Use of water for operating the building	Dismantling/Demolition	Transportation	Waste treatment and recycling	Disposal at landfill	Credit from C3: Waste treatment and recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	NDM	NDM	NDM	NDM	NDM	X	NDM	NDM	X	NDM	NDM	X

¹⁾ The stages of replacement (B4) and renewal (B5) are usually irrelevant at product level because they refer to future applications in the life cycle of the building. For reasons of clarity, these two stages were therefore deleted from the following tables.

Results of LCA Environmental Impacts 1 m²

		PLEXIGLAS® Resist SDP 16 – 32: Patio roofing (1 m ² = 4,3 kg)							PLEXIGLAS® Alltop SDP 16 – 64: Greenhouse roofing (1 m ² = 5 kg)						
ADPF	ADPE	POCP	EP	AP	ODP	GWP	Parameter	ADPF	ADPE	POCP	EP	AP	ODP	GWP	Parameter
							Unit								Unit
410,14	2,85E-6	4,73E-3	3,96E-3	44,6E-3	5,42E-9	18,13	A1-A3	410,14	2,85E-6	4,73E-3	3,96E-3	44,6E-3	5,42E-9	18,13	A1-A3
1,72	0,01E-6	-0,19E-3	0,14E-3	0,56E-3	0,00E-9	0,13	A4	1,72	0,01E-6	-0,19E-3	0,14E-3	0,56E-3	0,00E-9	0,13	A4
-2,70	-0,03E-6	-0,02E-3	-0,03E-3	-0,28E-3	-1,28E-9	0,13	A5	-2,70	-0,03E-6	-0,02E-3	-0,03E-3	-0,28E-3	-1,28E-9	0,13	A5
0	0	0	0	0	0	0	B6	0	0	0	0	0	0	0	B6
0,17	0,00E-6	-0,02E-3	0,01E-3	0,05E-3	0,00E-9	0,01	C2	0,17	0,00E-6	-0,02E-3	0,01E-3	0,05E-3	0,00E-9	0,01	C2
3,4	0,08E-6	0,08E-3	0,15E-3	0,79E-3	0,09E-9	8,53	C3	3,4	0,08E-6	0,08E-3	0,15E-3	0,79E-3	0,09E-9	8,53	C3
-101,05	-0,69E-6	-0,96E-3	-1,00E-3	-9,82E-3	-1,45E-9	-5,76	D	-101,05	-0,69E-6	-0,96E-3	-1,00E-3	-9,82E-3	-1,45E-9	-5,76	D
311,68 (72,48)	2,22 (0,52) E-06	3,61 (0,84) E-03	3,24 (0,75) E-03	36,1 (8,40) E-03	2,78 (0,62) E-9	21,29 (4,95)	Total	311,68 (72,48)	2,22 (0,52) E-06	3,61 (0,84) E-03	3,24 (0,75) E-03	36,1 (8,40) E-03	2,78 (0,62) E-9	21,29 (4,95)	Total
476,00	3,33E-6	5,48E-3	4,63E-3	51,73E-3	7,91E-9	21,05	A1-A3	476,00	3,33E-6	5,48E-3	4,63E-3	51,73E-3	7,91E-9	21,05	A1-A3
2,00	0,01E-6	-0,22E-3	0,16E-3	0,65E-3	0,00E-9	0,15	A4	2,00	0,01E-6	-0,22E-3	0,16E-3	0,65E-3	0,00E-9	0,15	A4
-2,86	-0,03E-6	-0,02E-3	-0,03E-3	-0,34E-3	-2,12E-9	0,15	A5	-2,86	-0,03E-6	-0,02E-3	-0,03E-3	-0,34E-3	-2,12E-9	0,15	A5
34459	41,82E-6	122E-3	225E-3	1041E-3	8,63E-9	2020,96	B6	34459	41,82E-6	122E-3	225E-3	1041E-3	8,63E-9	2020,96	B6
0,19	0,00E-6	-0,02E-3	0,02E-3	0,06E-3	0,00E-9	0,01	C2	0,19	0,00E-6	-0,02E-3	0,02E-3	0,06E-3	0,00E-9	0,01	C2
1978	0,16E-6	0,17E-3	0,23E-3	2,01E-3	0,49E-9	2,40	C3	1978	0,16E-6	0,17E-3	0,23E-3	2,01E-3	0,49E-9	2,40	C3
-39970	-3,21E-6	4,60E-3	-3,75E-3	-42,93E-3	-2,20E-9	-17,38	D	-39970	-3,21E-6	4,60E-3	-3,75E-3	-42,93E-3	-2,20E-9	-17,38	D
34554 (6911)	42,58 (8,52) E-06	122,8 (24,6) E-03	226,3 (45,3) E-03	1052 (210) E-03	12,70 (2,54) E-09	2027,4 (405,5)	Total	34554 (6911)	42,58 (8,52) E-06	122,8 (24,6) E-03	226,3 (45,3) E-03	1052 (210) E-03	12,70 (2,54) E-09	2027,4 (405,5)	Total

Legend

GWP = Global warming potential; ODP = Ozone depletion potential; AP = Acidification potential of soils and water; EP = Eutrophication potential; TOFP = Tropospheric ozone formation potential; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil fuels

Results of LCA Use of Resources for 1 m²

PLEXIGLAS® Resist SDP 16 – 32: Patio roofing (1 m ² = 4,3 kg)										PLEXIGLAS® Alltop SDP 16 – 64: Greenhouse roofing (1 m ² = 5 kg)											
Parameter	Unit	Production		Installation		Operation		Disposal		Credit	Total	Production		Installation		Operation		Disposal		Credit	Total
		A1-A3	A4	A5	B6	C2	C3	D	/m ² (/kg)			A1-A3	A4	A5	B6	C2	C3	D	/m ² (/kg)		
PERE	[MJ]	7,83	0,10	-0,28	0	0,01	0,36	-6,43	1,60 (0,37)		1,60 (0,37)	9,08	0,12	-0,29	19,80	0,01	2,33	-4,85	26,20 (5,24)		
PERM	[MJ]	0,00	0,00	0,00	0	0,00	0,00	0,00	0,00 (0,00)		0,00 (0,00)	0,00	0,00	0,00	0	0,00	0,00	0,00	0,00 (0,00)		
PERT	[MJ]	7,83	0,10	-0,28	0	0,01	0,36	-6,43	1,60 (0,37)		1,60 (0,37)	9,08	0,12	-0,29	19,80	0,01	2,33	-4,85	26,20 (5,24)		
PENRE	[MJ]	446,00	1,85	-3,08	0	0,18	3,68	-110,00	338,65 (78,76)		338,65 (78,76)	517,70	2,15	-3,27	38200	0,21	21,47	-434,9	38303 (7661)		
PENRM	[MJ]	0,00	0,00	0,00	0	0,00	0,00	0,00	0,00 (0,00)		0,00 (0,00)	0,00	0,00	0,00	0	0,00	0,00	0,00	0,00 (0,00)		
PENRT	[MJ]	446,00	1,85	-3,08	0	0,18	3,68	-110,00	338,65 (78,76)		338,65 (78,76)	517,70	2,15	-3,27	38200	0,21	21,47	-434,9	38303 (7661)		
FW	[MJ]	7,02	0,01	-0,23	0	0,00	0,35	-5,81	1,34 (0,31)		1,34 (0,31)	8,16	0,01	-0,24	11,40	0,89 E-3	2,10	-5,40	16,71 (3,34)		

Legend

PERE = Use of renewable primary energy; PERM = Use of renewable primary energy resources as raw materials; PERT = Total renewable primary energy;
 PENRE = Use of non-renewable primary energy; PENRM = Use of non-renewable primary energy resources as raw materials;
 PENRT = Total non-renewable primary energy; SM = Use of secondary materials; RSF = Use of renewable secondary fuels;
 NRSF = Non-renewable secondary fuels; FW = Use of freshwater resources; energy sources are stated as net values.

Results of LCA Output Flows and Waste Categories for 1 m²

		PLEXIGLAS® Resist SDP 16 – 32: Patio roofing (1 m ² = 4,3 kg)							PLEXIGLAS® Alltop SDP 16 – 64: Greenhouse roofing (1 m ² = 5 kg)								
		Production	Installation	Operation	Disposal	Credit	Total	Production	Installation	Operation	Disposal	Credit	Total				
Parameter	Unit	A1-A3	A4	A5	B6	C2	C3	D	/m ² (/kg)	A1-A3	A4	A5	B6	C2	C3	D	/m ² (/kg)
HWD	[kg]	2,66 E-3	0,00 E-3	0,35 E-3	0	0,00 E-3	8,40 E-3	0,27 E-3	11,14 (2,59) E-03	3,10E-3	0,00E-3	0,35E-3	0,00E-3	0,00E-3	1,09E-3	-2,76E-3	1,77 (0,35) E-3
NHWD	[kg]	19,54	0,01	-0,57	0	0,001	0,77	-13,92	5,91 (1,37)	22,74	0,01	-0,61	26,8	0,00 E-3	4,89	-14,33	39,51 (7,90)
MFR	[kg]	0	0	0	0	0	0,43	0	0,43 (0,10)	0	0	0	0	0	4,50	0	4,50 (0,90)
MER	[kg]	*	0	0,13	0	0	3,87	0	4,00 (0,93)	*	0	0,15	0	0	0,5	0	0,65 (0,13)
EE [therm]	[MJ]	*	0	1,31	0	0	30,3	0	31,61 (7,35)	*	0	1,53	0	0	3,92	0	5,45 (1,09)
EE [elektr]	[MJ]	0	0,55	0	0	12,6	0	13,15 (3,06)	0,64	0	0	1,63	0	0	0	2,27 (0,45)	

Legend

HWD = Hazardous waste disposal; NHWD = Non-hazardous waste disposal; RWD = Radioactive waste disposal; CRU = Components for reutilization; MFR = Material for recycling; MER = Material for energy recovery; EE = Exported energy per type; * The energy and feedstocks recovered in the manufacturing processes and during feedstock production cannot be explicitly captured, but are included in the result.

6 LCA: Interpretation

The primary energy requirement of the products made of PLEXIGLAS® is dominated by production (modules A1-A3), apart from module B6 of greenhouse glazing, which generates a very high energy requirement during the product's service life. Approx. 98% of this energy requirement is accounted for by non-renewable primary energy. In the case of patio roofing with PLEXIGLAS® Resist, about one quarter of the primary energy required during production can be recredited. In the case of greenhouse glazing with PLEXIGLAS® Alltop, this applies to more than 80% of primary energy. This results from the assumed recycling ratio.

The proportion of non-hazardous waste accounts for the largest share of waste disposal. In the case of patio roofing, approx. 71% of the waste caused during production can be credited, mainly due to energy recovery. During use in greenhouse construction, part of the volume saved through credits is offset by the waste that arises due to the amounts of electrical energy required for the recycling process. For this application, the wastes produced during the product's service phase are of the same volume as those produced during manufacture.

The water required for production is mainly related to the provision of energy. At 90% conversion to energy, about 50% of this water can be avoided through energy credits. In the case of the higher recycling ratio, the figure is only 32%. Conversion to energy of the PLEXIGLAS® products therefore considerably reduces water consumption over the entire life cycle.

The major share (> 50%) of emissions in the categories examined for the manufacture of PLEXIGLAS® multi-skin sheets (that are of relevance to the stated impact categories) results from the feedstocks used. Apart from greenhouse applications, where the thermal energy requirement of the service phase is clearly

dominant, these are decisive for the examined scenarios. The combustion processes during manufacture constitute another influencing factor.

One exception is the ODP, only approx. 20% of which are due to feedstocks during the production process, since this gives rise to relevant emissions, particularly during combustion processes. In this category, there are therefore credits in modules A5 and C3, in which energy recovery takes place and a credit is made for the generated heat and electricity.

Apart from the GWP, credits are made for the stated reasons in modules A5 and C3 in all other categories examined, because the combustion of PMMA gives rise to CO₂ emissions in particular. Transportation plays a subordinate role in all impact categories.

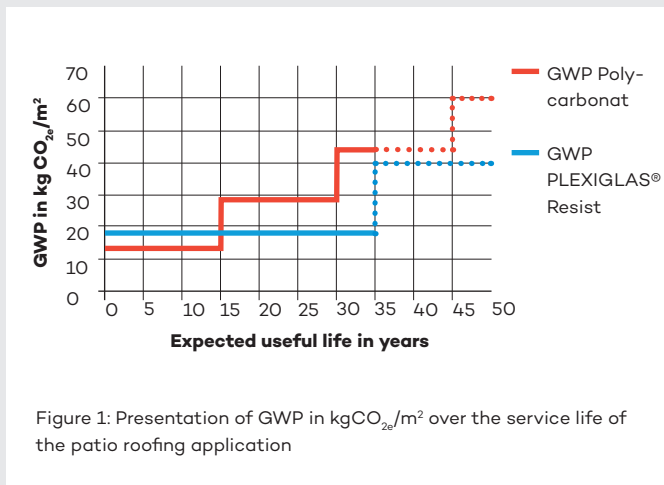
Differences in the environmental impacts of the multi-skin sheets examined here in categories A1 to A3 result almost exclusively from their different weights per unit area. The specific emissions of the starting products are the same, since manufacture is identical up to the PMMA stage.

The assumptions regarding the recycling ratios and the associated credits give rise to significant credits in all impact categories. The LCA, including the end-of-life assessment for large-scale applications, is therefore much more positive due to the assumed higher recycling ratio. At the same time, the different assumptions about the recycling ratios of the two applications also show the possible sensitivity of the results.

The stability and validity of the results were examined by means of sensitivity analyses of the relevant influencing parameters and allocations. Deviations for manufacture are in the single-digit percentage range.

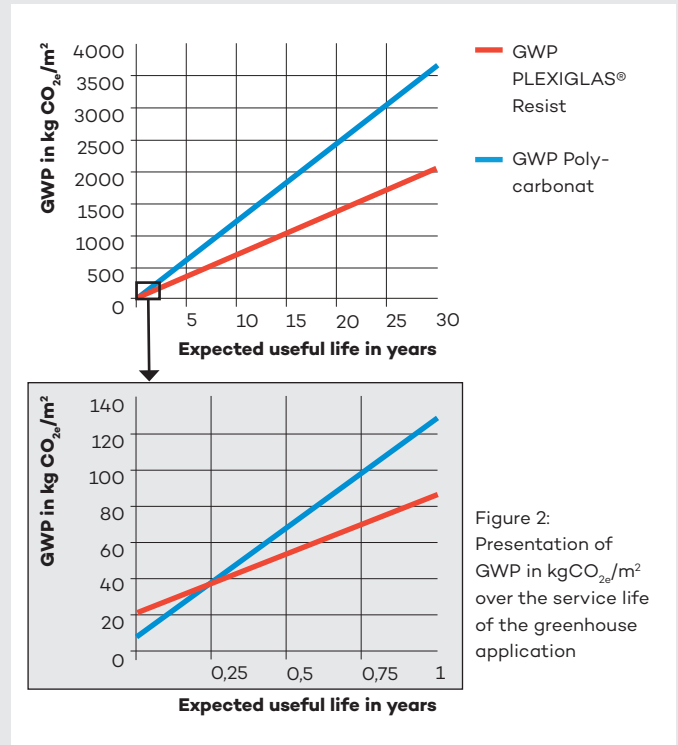
7 Classification of Results

To classify the results of this study, the following graphics show possible results of alternative materials used at present in the two same applications, using the global warming potential GWP as an example. Similar results are achieved in the other environmental categories.



Given an assumed service life of the patio roofing of 35 years and an assumed service life of the polycarbonate sheet of 15 years, the latter would need to be replaced twice during the service phase. The end-of-life (C3 and D) is taken into account in the event of replacement. The greenhouse gas potential of the polycarbonate sheet rises sharply over the life cycle, although it produces fewer emissions at the start of the life phase due in part to its lower weight per unit area.

Owing to its lower heat transfer index (U-value), PLEXIGLAS® Alltop SDP 16 – 64 has a positive influence on the energy consumption of a greenhouse. Compared with glass, this makes it possible to save almost half of the energy required during operation and the resulting emissions. The higher production-related emissions are therefore offset again within the first year.



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