Carbofol®

Environmental Product Declaration

Declarationnumber:
EPD-NAUE-CF-001-ref2 2017

NAUE

Environmental Product Declaration (EPD)
Carbofol®

Declaration holder
NAUE GmbH & Co. KG
Gewerbestraße 2
D-32339 Espelkamp
Phone: +49 5743 41-0
info@naue.com
www.naue.com

Declared product:
NAUE Carbofol®, geosynthetic for sealing

Data calculation by
treeze Ltd.
Kanzleistrasse 4
CH-8610 Uster
www.treeze.ch

Programme Operator	NAUE GmbH & Co. KG
Date of publication	23 November 2020
EPD validity	December 2025
EPD valid within following geographical area:	Global
CEN standard EN 15804:2012+A2:2019 serves as the core PCR	
Independent verification of the declaration and data, according to EN ISO 14025:2010 ☒ internal ☐ external	

1. General aspects
This Environmental Product Declaration (EPD) is commissioned by NAUE GmbH & Co. KG and accomplished by treeze Ltd. in 2020. The study has been conducted according to the requirements of the standard EN 15804:2012+A2:2019 (EN 15804, 2019) and IES product category rules (IES 2018). The investigated products are the NAUE geosynthetics Carbofol® PP intended for the use in many fields of civil engineering including landfill engineering and hydraulic engineering.

This EPD is a revision and extension of a work done in 2017 for the same kind of geosynthetics (NAUE 2017). In comparison to 2017, the data are evaluated based on new background inventory where available. Furthermore, in this revision also the "end-of-life stage" (C1 – C4) is evaluated.

2 Product

2.1 Description and application

The investigated products belong to the NAUE product family Carbofol® intended for the use in many fields of civil engineering. The raw material and energy demand are based on the annual production of Carbofol® and do not reflect a specific product but the product family. The classification number according to the UN CPC classification system is 36950.

Carbofol® geosynthetics provide a complete seal against even the most toxic substances and are installed as a component of landfill base seals as well as caps. Carbofol® protects groundwater from contamination. Even the strictest regulations and controls for the storage, filling, handling, manufacturing, treatment and use of contaminated liquids are easily satisfied with Carbofol®. The product is also suitable for potable water and non-toxic containment applications such as water conveyance structures, canals, or ponds. Individual solutions can also be developed for steeper slopes utilising our structured surface material with higher friction coefficients for greater safety.

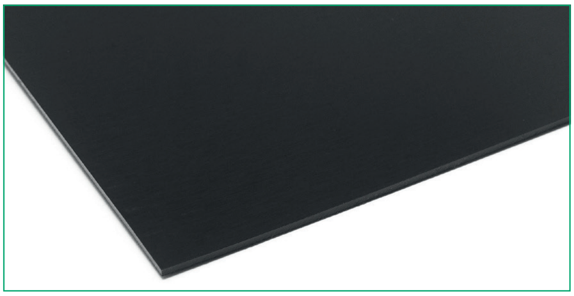

Figure 1
Carbofol® Smooth

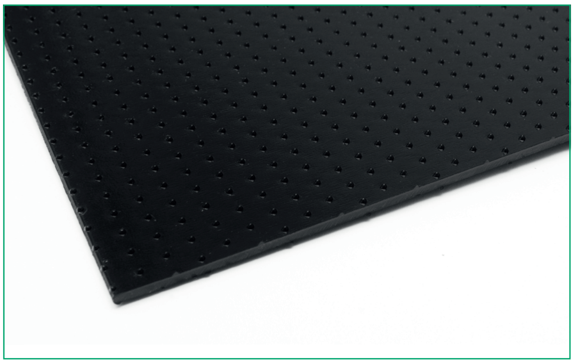

Figure 2
Carbofol® Friction

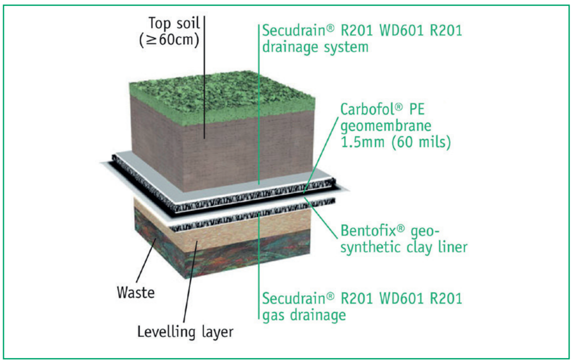

Figure 3
Carbofol® - landfill capping system

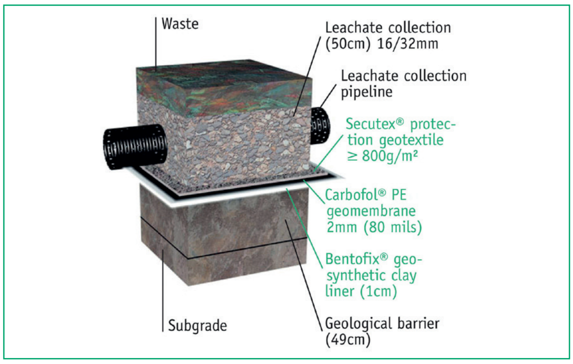

Figure 4
Carbofol® - landfill base lining system

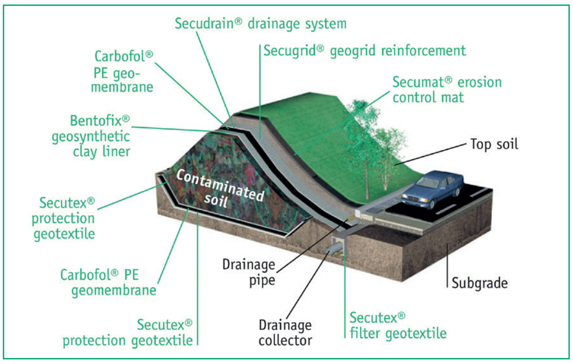

Figure 5
Carbofol® - Encapsulation of contaminated soil

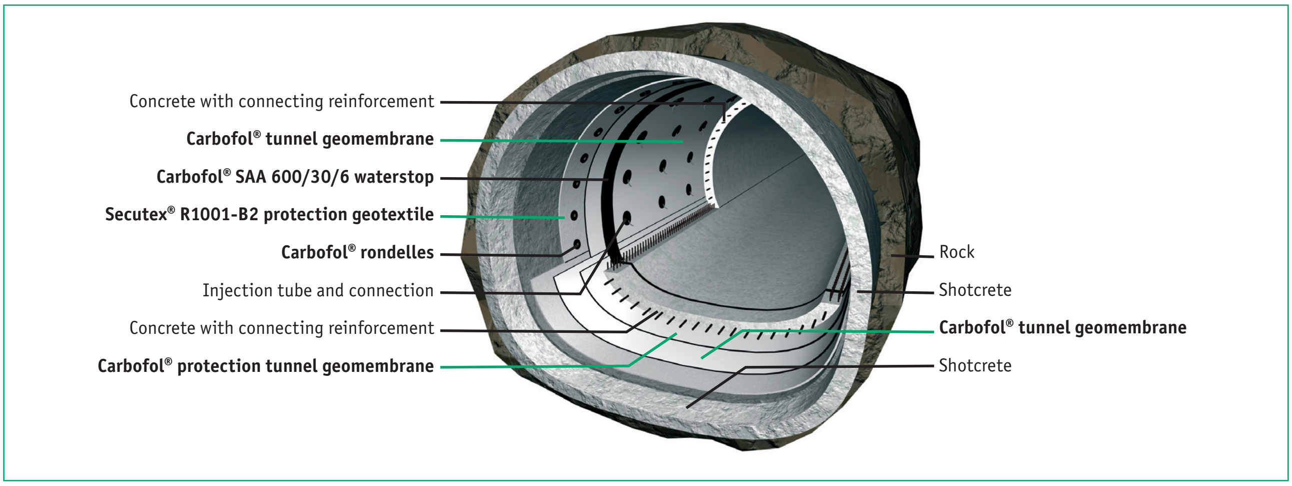

Figure 6
Tunnel design of a 360° sealing with Carbofol® and an integrated injection system

Product stage			Construction process stage		Use stage	End-of-life stage			
Raw material supply	Transport	Manufacturing	Downstream transport (to construction site)	Construction-Installation process	Use	Deconstruction, demolition	Transport	Waste processing	Disposal
A1	A2	A3	A4	A5	B1-B7	C1	C2	C3	C4
X	X	X	X	X	n.a.	X	X	X	X

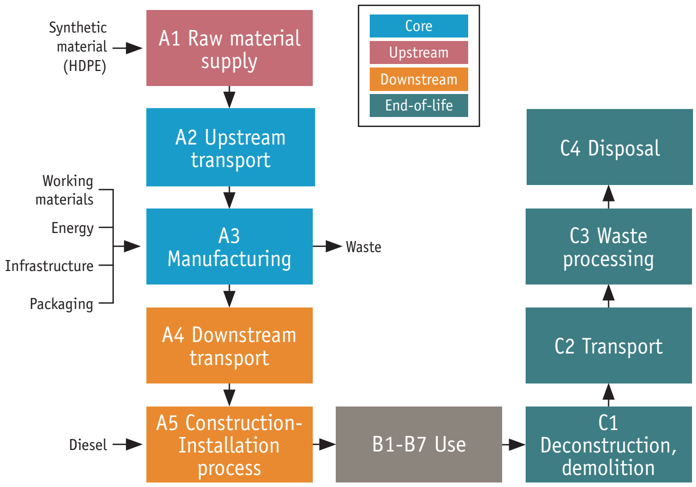

Figure 7
Graphical overview of the life cycle stages covered by the EPD of geosynthetics

2.2 Raw material (A1)
The geosynthetic product Carbofol® is manufactured using high-density polyethylene (HDPE) as raw material. The geosynthetic consists of 93% HDPE and 7% Carbon Black. The material composition was modelled as pure HDPE to simplify the calculations. This leads to a minor over- or underestimation of the environmental impacts depending on the impact categories. More detailed information on the materials used is shown in Tab.1.

2.3 Transport (A2)
The transport to the manufacturer (A2) considers transports of raw materials to the NAUE manufacturing site. The raw materials are transported from the producer to the NAUE's production site by lorry only. The average shipping distances for HDPE and Carbon Black are 709km and 470km, respectively.

Figure 8
Carbofol® production

2.4 Manufacturing (A3)
The manufacturing stage (A3) includes working materials, energy consumption, disposal of production wastes (scrap, lubricating oil and municipal waste), the infrastructure (factory halls and office buildings and the corresponding land use), and the product's packaging. The manufacturing site is in Germany. Therefore, the German consumption mix at low voltage level is used to model the electricity use in manufacturing. The consumption mix displays the electricity domestic net production including imports. 6.1% secondary plastics are used, and the HDPE production waste is about 0.7% relative to the material input.

Figure 9
Carbofol® loading

2.5 Downstream transport (A4)
Transports from the manufacturer to the customer, merchant or distribution platform are considered based on the current sales of NAUE. Shipping within Europe is realised by lorry and to the rest of the world mainly by means of freight ships. Shipped geosynthetics are transported to port by lorry.

2.6 Construction and installation (A5)
The construction and installation stage considers the mounting of Carbofol®. Other processes such as excavation of foundation or ground compaction are outside the system boundary. The diesel consumption of mounting the geosynthetics amounts to 2.47MJ/m².

Figure 10
Carbofol® installation

2.7 Deconstruction (C1)
The deconstruction as part of the end-of-life processes (C1) covers the on-site dismantling of Carbofol®. The diesel consumption of dismantling the geosynthetics amounts to 10.1MJ/m².

2.8 Transport to product's waste processing (C2)
The end-of-life transport (C2) considers the transportation of the geosynthetics to a recycling site or disposal. On average, Carbofol® is transported 48km to the nearest waste incineration plant or landfill.

2.9 Waste processing (C3)
Carbofol® is directly disposed of. That is why no wasted processing is included in the assessment.

2.10 Disposal (C4)
The end-of-life disposal (C4) includes the emissions from waste disposal, physical pre-treatment, and management of the disposal site. Carbofol® is disposed of 80% in municipal waste incineration plants and 10% in landfills, while 10% is recycled.

3 LCA – Calculation rules
3.1 Declared unit
The declared unit is 1m² of geomembrane of the product family Carbofol® with an average mass per unit area of 1.703g/m².

3.2 System boundaries
This EPD is a cradle-to-grave declaration excluding the usage stage. The product system of geosynthetics comprises the product stage (manufacture and supply of raw materials including purchase and inter-company logistics, manufacture of the components and of the product), the construction stage (mounting of the product) and the end-of-life stage (deconstruction, end-of-life transport and disposal).

The comparison of products based on their EPD is defined by the contribution they make to the environmental performance of the building. Consequently, the comparison of the environmental performance of construction products using the EPD information shall be based on the product's use in and its impacts on the building and shall consider the complete life cycle (all information modules).

Specific material consumption	Specific material and energy use per m²	Unit	Carbofol®
Production volume and reference year	Annual production volume	tons	*
	Annual production volume	m²	*
	Reference year		2019
	Mass per unit area	g/m²	1'703
A1 Raw material	Recycling material	g/m2	105.2
	Polyethlyene (HDPE)	g/m²	1'609.6
A2 Upstream transport	Lorry, 25 tons	tkm/m²	1.11E+00
A3 Manufacturing (working material and energy consumption)	**Working material**		
	Tap water	kg/m²	1.17E-01
	Lubricating oil	kg/m²	4.82E-05
	Packaging		
	Paper case / cardboard	kg/m²	2.42E-02
	LLDPE (Packaging)	kg/m²	2.18E-04
	PVC	kg/m²	1.18E-02
	Energy		
	Electricity	kWh/m²	6.23E-01
	Diesel	MJ/m²	7.18E-02
	Waste		
	Municipal waste	kg/m²	2.81E-04
	Hazardous waste (machine oil)	kg/m²	2.57E-05
	HDPE to recycling	kg/m²	1.15E-02
	Wastewater	m³/m²	1.12E-02
	Land use		
	Total area	m²/m²	7.74E-04
	Factory halls	m²/m²	2.31E-04
	Office buildings	m²/m²	1.97E-05
	Other sealed area	m²/m²	4.40E-04
	Share related to product	%	10%
A4 Downstream transport	Ship	tkm/m²	9.53E+00
	Lorry, 25 tons	tkm/m²	1.36E+00
A5 Construction and installation	Diesel consumption installation	MJ/m²	2.47E+00
C1 Deconstruction	Diesel consumption deconstruction	MJ/m²	1.01E+01
C2 End-of-life transport	Lorry, 25 tons	tkm/m²	8.18E-02
C4 Disposal	Municipal waste incineration, HDPE	kg/m²	1.36E+00
	Landfill, HDPE	kg/m²	1.70E-01
	Recycling	kg/m²	1.70E-01

Table 1
Specific raw material, working material and energy consumption, wastes produced and infrastructure requirements per square meter of average geomembrane of the product family Carbofol®

* filed confidentially
** tkm/m² - ton-kilometer per m²

3.3 Allocation and recycling
Wastes that reach the end of waste state and that are recycled leave the product system without bearing a share of the environmental impacts of the first life cycle. No credits are given for potentially avoided production. Secondary raw materials bear environmental impacts caused by scrap collection and recycling activities. This is in line with the "polluter pays" principle (EN 15804, 2019; IES 2012)

Energy and working materials consumption as well as infrastructure requirements of Carbofol® manufacture are allocated according to the m² of the geosynthetics outputs.

3.4 Temporal and geographic validity
The life cycle assessment of Carbofol® describes the geosynthetics used worldwide. It is valid for the purchase, production, and distribution situation in the recent past (last two years). All product alternatives described in this report are currently available on the market.

3.5 Background data
Foreground inventory data is mainly based on average annual production data provided by NAUE GmbH & Co. for the year 2019. The primary sources of background inventory data are the UVEK LCI data DQRv2:2018 (KBOB et al. 2018). These data are based on the ecoinvent data v2.2 (ecoinvent Centre 2010) and include updates of several background inventory data: electricity supply (Itten et al. 2014; Messmer & Frischknecht 2016a), natural gas supply (Schori et al. 2012), photovoltaics (Jungbluth et al. 2012; Frischknecht et al. 2015a), hydroelectric power generation (Flury & Frischknecht 2012), nuclear power and supply chain (Bauer et al. 2012), oil supply chain (Stolz & Frischknecht 2016a), wood products (Werner 2017), aluminium (Stolz & Frischknecht 2016b) and transportation (Stolz et al. 2016; Messmer & Frischknecht 2016b, c, d). The plastics inventory data of PET and PP refer to the years 1999/2000 and 1999, respectively and are based on data provided by PlasticsEurope (Boustead 2005-07).

The modelling and all calculations are performed with the LCA software SimaPro v9.1 (PRé Consultants 2020).

4 LCA – Results

LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks. Impact category indicators required by the environmental product declaration standard were modelled as follows:

- Climate change – total: Global warming potential total (GWP-total), Baseline model of 100 years of the IPCC based on IPCC (2013).
- Ozone depletion: Depletion potential of the stratospheric ozone layer (ODP), steady state ODPs (WMO 2015).
- Acidification: Acidification potential, Accumulated exceedance (Seppälä et al. 2006, Posch et al. 2008).
- Eutrophication aquatic freshwater: Eutrophication potential, fraction of nutrients reaching freshwater end compartment (EP-freshwater), EUTREND model (Struijs et al. 2009).
- Eutrophication aquatic marine: Eutrophication potential, fraction of nutrients reaching marine end compartment (EP-marine): EUTREND model (Struijs et al. 2009).
- Eutrophication terrestrial: Eutrophication potential (EP-terrestrial), Accumulated exceedance (Seppälä et al. 2006, Posch et al. 2008).
- Photochemical ozone formation: Formation potential of tropospheric ozone (POCP), LOTOS-EUROS (Van Zelm et al. 2008).
- Depletion of abiotic resources – minerals and metals: Abiotic depletion potential for non-fossil resources (ADP-minerals & metals), CML 2002 (van Oers et al. 2002).
- Depletion of abiotic resources – fossil fuels1: Abiotic depletion potential for fossil resources (ADP-fossil), CML 2002 (van Oers et al. 2002).
- Water use1: Water (user) deprivation potential, deprivation weighted water consumption (WDP), Available WAter REmaining (AWARE, Boulay et al. 2017).
- Particulate Matter (PM) emissions: Potential incidence of disease due to PM emissions, SETAC-UNEP (Fantke et al. 2016).
- Ionising radiation, human health: Potential human exposure efficiency relative to U235 (IRP), human health effect model as developed by Dreicer (1995) update by Frischknecht (2000).
- Ecotoxicity (freshwater)1: Potential comparative toxic unit for ecosystems (ETP-fw), USEtox model (DG-JRC 2015).
- Human toxicity, cancer effects1: Potential comparative toxic unit for humans (HTP-c), USEtox model (DG-JRC 2015).
- Human toxicity, non-cancer effects1: Potential comparative toxic unit for humans (HTP-nc), USEtox model (DG-JRC 2015).
- Land use related impacts / soil quality1: Potential soil quality index (SQP), soil quality index based on LANCA.
- Use of renewable and non-renewable energy (cumulative energy demand, CED): reported in net calorific value, as demanded in the product declaration guidelines. For each the total and the two sub-categories "primary energy resources used as raw material" (feedstock) and "primary energy resources excluding use as raw material" are reported.
- The "CED, raw materials used" was assessed on product basis, i.e. the net calorific value of the materials contained in the geosynthetics.
- The "CED total, renewable" and "CED total, non-renewable" are calculated with the method published in ecoinvent version 2.0 and expanded by PRé Consultants for resources available in SimaPro 9 database (Frischknecht et al. 2007; Frischknecht et al. 2015b; PRé Consultants 2015).
- Use of secondary materials: based on the feedstock used in the production of the geosynthetics.
- Use of renewable secondary fuels and use of non-renewable secondary fuels. Electricity is assumed to contain no secondary fuels.
- Use of net fresh water: Evaporated water is considered with 100%; elementary flows in the background system are accounted for as follows: 10% of water extracted from water bodies and 10% of process water used (e.g. Water, lake; Water, process, drinking) and 5% of cooling water used (e.g. water, cooling, surface).
- Waste, life cycle based: "Hazardous waste" covers hazardous waste deposited in underground storage facilities and is accounted for via the elementary flow of volume occupied in an underground deposit. The density of hazardous waste for the conversion to kg is taken from the ecoinvent report 13-III (Doka 2009). "Radioactive waste" covers low radioactive waste and high and medium radioactive waste. It is assessed likewise via the elementary flows "volume occupied, final repository for radioactive waste" and "volume occupied, final repository, low-active waste", respectively. The density of radioactive waste is taken from Dones (Dones 2007). Non-hazardous waste covers all waste going to landfills. The conversion of the land transformation elementary flows "transformation, to dumpsite" for slag compartment (22'500kg/m^2), inert material landfill (22'500kg/m^2), sanitary landfill (20'000kg/m^2) and residual material landfill (16'000kg/m^2) is conducted according to the average depth of the landfill sites and average waste densities given in Doka (2007).
- Materials for recycling: based on the materials wasted in production, i.e. PET and PP sold to the recycling company. The share of the waste for PP is 3.15% relative to the material input.
- Materials for energy recovery: weight of materials sent to municipal waste incineration plant, i.e. municipal waste.
- Long-term emissions are not included in the assessment because of implausible results of the indicator eutrophication.

[1] The results of this environmental impact indicator shall be used with care as the uncertainties on these results are high or as there is limited experience with the indicator.

[2] This impact category deals mainly with the eventual impact of low dose ionizing radiation on human health of the nuclear fuel cycle. It does not consider effects due to possible nuclear accidents, occupational exposure nor due to radioactive waste disposal in underground facilities. Potential ionizing radiation from the soil, from radon and from some construction materials is not either quantified by this indicator.

4.1 Life cycle impact assessment results

Environmental Impact 1m² Carbofol 1703g/m²	**Unit**	**A1 Raw material supply**	**A2 Up-stream transport**	**A3 Manufac-turing**	**A4 Down-stream transport**	**A5 Construc-tion and installa-tion**	**C1 Decon-struction**	**C2 End-of-life transport**	**C4 Disposal**
Climate change - total	kg CO_2-eq.	3.43E+00	1.39E-01	4.56E-01	2.36E-01	2.53E-01	1.03E+00	1.02E-02	4.15E+00
Ozone depletion	kg CFC-11-eq	5.07E-10	7.33E-09	1.59E-08	1.10E-08	1.18E-08	4.80E-08	5.38E-10	4.60E-09
Acidification (AP)	kg H^+-eq	1.25E-02	6.06E-04	1.07E-03	2.98E-03	1.22E-03	4.98E-03	4.45E-05	5.44E-04
Eutrophication aquatic freshwater	kg PO_4^{3-}-eq	1.72E-06	2.13E-06	7.11E-05	3.64E-06	1.60E-06	6.52E-06	1.56E-07	5.54E-07
Eutrophication aquatic marine	kg N-eq	2.04E-03	1.43E-04	4.39E-04	7.28E-04	3.93E-04	1.60E-03	1.05E-05	2.60E-04
Eutrophication terrestrial	kg N-eq	2.22E-02	1.58E-03	2.50E-03	8.07E-03	4.32E-03	1.76E-02	1.16E-04	2.77E-03
Photochemical ozone formation	kg NMVOC-eq	1.38E-02	5.43E-04	7.49E-04	2.24E-03	1.28E-03	5.21E-03	3.99E-05	6.74E-04
Depletion of abiotic resources - minerals and metals	kg Sb-eq	4.50E-08	3.26E-07	6.56E-07	4.05E-07	6.43E-08	2.62E-07	2.39E-08	3.15E-08
Depletion of abiotic resources - fossil fuels	MJ oil-eq	1.15E+02	2.16E+00	7.49E+00	3.59E+00	3.45E+00	1.41E+01	1.59E-01	5.94E-01
Water use	m^3 world eq. deprived	3.48E+00	7.09E+00	6.74E+01	1.27E+01	5.49E+00	2.24E+01	5.20E-01	2.38E+00
Particulate matter emissions	disease inci-dence	1.23E-07	1.02E-08	8.42E-09	1.45E-08	6.26E-09	2.55E-08	7.50E-10	2.24E-09
Ionising radiation, human health	kBq U235-eq	6.08E-04	3.54E-03	4.09E-02	7.01E-03	2.61E-03	1.06E-02	2.60E-04	1.03E-03
Ecotoxicity (freshwater)	CTUe	1.42E+00	1.58E+00	6.78E+00	2.50E+00	2.08E+00	8.47E+00	1.16E-01	8.27E-01
Human toxicity, cancer effects	CTUh	2.46E-10	4.30E-11	1.53E-10	7.19E-11	1.38E-10	5.64E-10	3.16E-12	1.31E-10
Human toxicity, non-cancer effects	CTUh	2.43E-08	2.41E-09	4.43E-09	3.37E-09	3.03E-09	1.24E-08	1.77E-10	5.80E-09
Land use related impacts / soil quality	-	4.72E-02	4.11E-01	5.49E+00	6.35E-01	3.77E-01	1.54E+00	3.02E-02	1.67E-01

Table 2
Environmental impact caused by the production of 1 square meter of the average geomembrane of the product family Carbofol®.

Energy Demand 1m² Carbofol 1703g/m²	**Unit**	**A1 Raw material supply**	**A2 Up-stream transport**	**A3 Manufac-turing**	**A4 Down-stream transport**	**A5 Construc-tion and installa-tion**	**C1 Decon-struction**	**C2 End-of-life transport**	**C4 Disposal**
CED, non-renewable, total	MJ oil-eq	1.16E+02	2.16E+00	7.25E+00	3.58E+00	3.45E+00	1.41E+01	1.58E-01	6.08E-01
CED, non-ren., w/o raw mat. use	MJ oil-eq	4.77E+01	2.16E+00	6.99E+00	3.58E+00	3.45E+00	1.41E+01	1.58E-01	6.08E-01
CED, non-ren., raw mat. use	MJ oil-eq	6.84E+01	0.00E+00	2.60E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CED, renewable, total	MJ oil-eq	1.45E+00	3.56E-02	1.53E+00	6.60E-02	2.60E-02	1.06E-01	2.61E-03	1.12E-02
CED, renew., w/o raw material use	MJ oil-eq	1.45E+00	3.56E-02	1.53E+00	6.60E-02	2.60E-02	1.06E-01	2.61E-03	1.12E-02
CED, renew., raw material use	MJ oil-eq	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of renewable secondary fuels	MJ oil-eq	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of non-renewable secondary fuels	MJ oil-eq	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of electricity	MJ	0.00E+00	0.00E+00	2.24E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 3
Cumulative energy demand and energy use caused by the production of 1 square meter of average geomembrane of the product family Carbofol®.

Material Use 1m² Carbofol 1703g/m²	Unit	A1 Raw material supply	A2 Up-stream transport	A3 Manufac-turing	A4 Down-stream transport	A5 Construc-tion and installa-tion	C1 Decon-struction	C2 End-of-life transport	C4 Disposal
Use of net fresh water	m^3	2.87E-03	9.48E-05	1.78E-03	1.61E-04	8.11E-05	3.31E-04	6.95E-06	1.13E-04
Hazardous waste	kg	3.56E-07	2.64E-06	2.20E-05	3.64E-06	1.54E-06	6.28E-06	1.94E-07	3.99E-06
Non-hazardous waste	kg	3.72E-02	1.66E-02	2.32E-02	2.10E-02	4.01E-03	1.63E-02	1.22E-03	2.37E-01
Radioactive waste	kg	4.42E-07	2.48E-06	4.83E-05	5.04E-06	1.94E-06	7.91E-06	1.82E-07	7.46E-07
Use of material	kg	1.61E+00	0.00E+00	3.63E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of renewable material	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of secondary material	kg	1.05E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of renewable secondary material	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for recycling	kg	0.00E+00	0.00E+00	1.15E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for energy recovery	kg	0.00E+00	0.00E+00	2.81E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 4
Material use and waste flows caused by the production of 1 square meter of average geomembrane of the product family Carbofol®.

4.2. Relative contribution of life cycle stages

Fig. 11 shows the relative contribution of the different life cycle stages (A1 – A5) to the total impact of the product and construction process stage A of Carbofol® geosynthetics. The contribution is shown for the ten core indicators: climate change – total, ozone depletion, acidification (AP), eutrophication aquatic freshwater, eutrophication aquatic marine, eutrophication terrestrial, photo-chemical ozone formation, depletion of abiotic resources – minerals and metals, depletion of abiotic resources – fossil fuels and water use. According to the EPD of 2017 (NAUE 2017) and for comparison purposes, the end-of-life stage C is not included in Fig. 11.

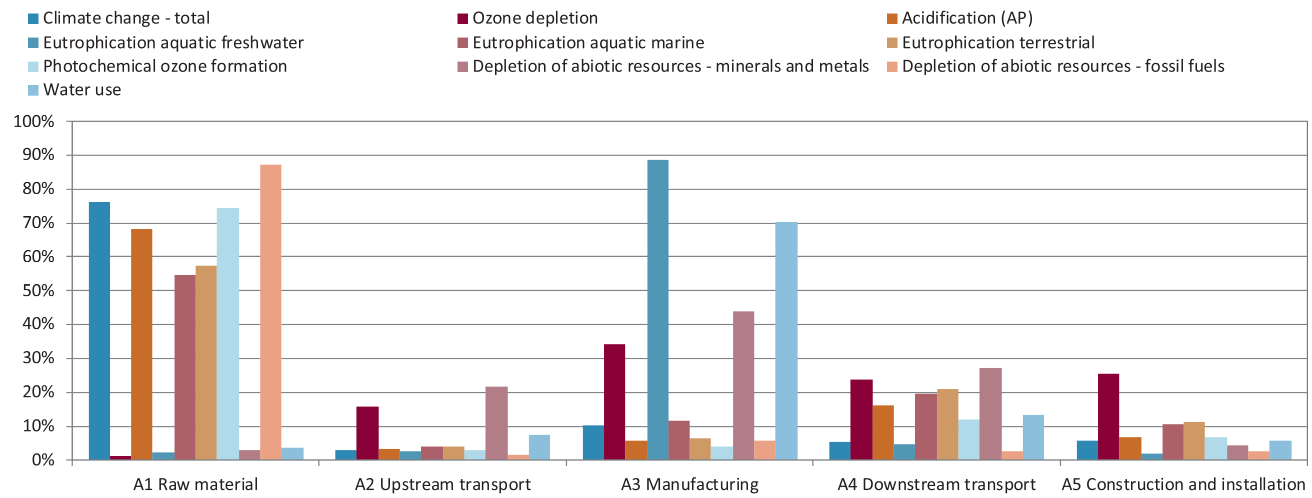

Figure 11
Relative contribution of the different life cycle stages (A1 – A5) to the total impact of the product and construction process stage A of Carbofol®.

4.3 Data quality

The quality of the data used to model geosynthetics produced by NAUE GmbH & Co. KG is high regarding the material composition, the transport logistics and the manufacture of components. Data are provided by NAUE GmbH & Co. KG and are reliable and detailed. The manufacturer's data are less than three years old and based on annual averages. The data representing the end-of-life stage are mainly based on assumptions and thus the data quality is considered to be low. The material supply of plastics is represented by best available data provided by the European Plastics Association PlasticsEurope.

The UVEK LCI data DQRv2:2018 (KBOB et al. 2018) are used as background inventory data to complement the product system of geosynthetics. The UVEK LCI data DQRv2:2018 are based on the ecoinvent data v2.2 (ecoinvent Centre 2010) and contain inventory data of many basic materials and services. The database includes the most recent datasets of plastic feedstock. Most of the important background data are less than 10 years old.

Additional data quality considerations are documented within the KBOB LCI and ecoinvent database. A Monte Carlo analysis to assess uncertainties was not conducted. The overall background data quality is appropriate for the use in this LCA.

5 References

Bauer et al. 2012	Bauer C., Frischknecht R., Eckle P., Flury K., Neal T., Papp K., Schori S., Simons A., Stucki M. and Treyer K. (2012) Umweltauswirkungen der Stromerzeugung in der Schweiz. ESU-services Ltd & Paul Scherrer Institute im Auftrag des Bundesamts für Energie BFE, Uster & Villigen.
Boulay et al. 2017	Boulay A.-M., Bare J., Benini L., Berger M., Lathuillière M., Manzardo A., Margni M., Motoshita M., Núñez M., Pastor A. V., Ridoutt B., Oki T., Worbe S. and Pfister S. (2017) The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on Available WAter REmaining (AWARE). In: The International Journal of Life Cycle Assessment, pp. 1-11, 10.1007/s11367-017-1333-8.
Boustead 2005-07	Boustead I. (2005-07) Electronic documents with the datasets from the PlasticsEurope Eco-Profiles - Calculation results from March 2005. PlasticsEurope, retrieved from: http://www.plasticseurope.org.
DG-JRC 2015	DG-JRC (2015) Executive summary of 'Current and future implementability of USEtox' PEF meeting, Final version May 2015. Institute for Environment and Sustainability, Joint Research Centre, European Commission, Ispra, I..
Doka 2007	Doka G. (2007) Life Cycle Inventories of Waste Treatment Services. ecoinvent report No. 13, v2.0. EMPA St. Gallen, Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.
Doka 2009	Doka G. (2009) Life Cycle Inventories of Waste Treatment Services. ecoinvent report No. 13, v2.1. EMPA St. Gallen, Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.
Dones 2007	Dones R. (2007) Kernenergie. In: Sachbilanzen von Energiesystemen: Grundlagen für den ökologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Ökobilanzen für die Schweiz, Vol. ecoinvent report No. 6-VII, v2.0 (Ed. Dones R.). Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Dübendorf, CH retrieved from: www.ecoinvent.org.
Dreicer et al. 1995	Dreicer M., Tort V. and Manen P. (1995) ExternE, Esternalities of Energy. Vol. 5 Nuclear (ed. European Commission DGXII S., Research and development JOULE). Centre d'Étude sur l'Evaluation de la Protection dans le Domaine Nucléaire (CEPN), Luxembourg, L.
ecoinvent Centre 2010	ecoinvent Centre (2010) ecoinvent data v2.2, ecoinvent reports No. 1-25. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.
EN 15804 2013	EN 15804 (2013) EN 15804:2012+A1:2013 - Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products. European Committee for Standardisation (CEN), Brussels, B.
EN 15804 2019	EN 15804 (2019) EN 15804:2012+A2:2019 - Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products. European Committee for Standardisation (CEN), Brussels, B.
Fantke et al. 2016	Fantke P., Evans J. S., Hodas N., Apte J. S., Jantunen M. J., Jolliet O. and McKone T. E. (2016) Health impacts of fine particulate matter. In: Global Guidance for Life Cycle Impact Assessment Indicators. UNEP, Paris, F.
Flury & Frischknecht 2012	Flury K. and Frischknecht R. (2012) Life Cycle Inventories of Hydroelectric Power Generation. ESU-services Ltd., Uster, CH, retrieved from: www.lc-inventories.ch.
Frischknecht et al. 2000	Frischknecht R., Braunschweig A., Hofstetter P. and Suter P. (2000) Human Health Damages due to Ionising Radiation in Life Cycle Impact Assessment. In: Review Environmental Impact Assessment, 20(2), pp. 159-189.
Frischknecht et al. 2007	Frischknecht R., Althaus H.-J., Dones R., Hischier R., Jungbluth N., Nemecek T., Primas A. and Wernet G. (2007) Renewable Energy Assessment within the Cumulative Energy Demand Concept: Challenges and Solutions. In proceedings from: SETAC Europe 14th LCA case study symposium: Energy in LCA - LCA of Energy, 3-4 December 2007, Gothenburg, S.
Frischknecht et al. 2015a	Frischknecht R., Itten R., Sinha P., de Wild Scholten M., Zhang J., Fthenakis V., Kim H. C., Raugei M. and Stucki M. (2015a) Life Cycle Inventories and Life Cycle Assessments of Photovoltaic Systems. International Energy Agency (IEA) PVPS Task 12.
Frischknecht et al. 2015b	Frischknecht R., Wyss F., Büsser Knöpfel S., Lützkendorf T. and Balouktsi M. (2015b) Cumulative energy demand in LCA: the energy harvested approach. In: The International Journal of Life Cycle Assessment, 20(7), pp. 957-969, 10.1007/s11367-015-0897-4, retrieved from: http://dx.doi.org/10.1007/s11367-015-0897-4.
IES 2012	IES (2012) Product Category Rules and PCR Basic Module. International EPD System (IES), retrieved from: www.environdec.com.
IES 2018	IES (2018) Product Category Rules (PCR) Construction Products and Construction Services, 2012:01, Version 2.3. International EPD System (IES), Stockholm, S, retrieved from: www.environdec.com.
IPCC 2013	IPCC (2013) The IPCC fifth Assessment Report - Climate Change 2013: the Physical Science Basis. Working Group I, IPCC Secretariat, Geneva, CH.

Itten et al. 2014	Itten R., Frischknecht R. and Stucki M. (2014) Life Cycle Inventories of Electricity Mixes and Grid, Version 1.3. treeze Ltd., Uster, CH, retrieved from: www.treeze.ch.
Jungbluth et al. 2012	Jungbluth N., Stucki M., Flury K., Frischknecht R. and Buesser S. (2012) Life Cycle Inventories of Photovoltaics. ESU-services Ltd., Uster, CH, retrieved from: www.esu-services.ch.
KBOB et al. 2018	KBOB, eco-bau and IPB (2018) UVEK Ökobilanzdatenbestand DQRv2:2018. Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren c/o BBL Bundesamt für Bauten und Logistik, retrieved from: www.ecoinvent.org.
Messmer & Frischknecht 2016a	Messmer A. and Frischknecht R. (2016a) Umweltbilanz Strommix Schweiz 2014. treeze Ltd., Uster, CH.
Messmer & Frischknecht 2016b	Messmer A. and Frischknecht R. (2016b) Life Cycle Inventories of Air Transport Services. treeze Ltd., Uster, CH.
Messmer & Frischknecht 2016c	Messmer A. and Frischknecht R. (2016c) Life Cycle Inventories of Water Transport Sevices. treeze Ltd., Uster, CH.
Messmer & Frischknecht 2016d	Messmer A. and Frischknecht R. (2016d) Life cycle inventories of rail transport services. treeze Ltd., Uster, CH.
NAUE 2017	NAUE (2017) Environmental Product Declaration Terrafix. NAUE GmbH & Co. KG, Espelkamp-Fiestel, D.
Posch et al. 2008	Posch M., Seppälä J., Hettelingh J. P., Johansson M., Margni M. and Jolliet O. (2008) The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA. In: Int J LCA(13), pp. 477-486.
PRé Consultants 2015	PRé Consultants (2015) SimaPro 8.0.6, Amersfoort, NL.
PRé Consultants 2020	PRé Consultants (2020) SimaPro 9.1.0.7, Amersfoort, NL.
Schori et al. 2012	Schori S., Bauer C. and Frischknecht R. (2012) Life Cycle Inventory of Natural Gas Supply. Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.
Seppälä et al. 2006	Seppälä J., Posch M., Johansson M. and Hettelingh J. P. (2006) Country-dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated exceedance as an Impact Category Indicator. In: Int J LCA, 11(6), pp. 403-416.
Stolz & Frischknecht 2016a	Stolz P. and Frischknecht R. (2016a) Energieetikette für Personenwagen: Umweltkennwerte 2016 der Strom- und Treibstoffbereitstellung. treeze Ltd., Uster, CH.
Stolz et al. 2016	Stolz P., Messmer A. and Frischknecht R. (2016) Life Cycle Inventories of Road and Non-Road Transport Services. treeze Ltd., Uster, CH.
Stolz & Frischknecht 2016b	Stolz P. and Frischknecht R. (2016b) Life Cycle Inventories of Aluminium and Aluminium Profiles. treeze Ltd., Uster, CH.
Struijs et al. 2009	Struijs J., Beusen A., van Jaarsveld H. and Huijbregts M. A. J. (2009) Aquatic Eutrophication. In: ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors (Ed. Goedkoop M., Heijungs R., Heijbregts M. A. J., De Schryver A., Struijs J. and Van Zelm R.).
van Oers et al. 2002	van Oers L., de Koning A., Guinée J. B. and Huppes G. (2002) Abiotic resource depletion in LCA. Road and Hydraulic Engineering Institute, Amsterdam, NL.
Van Zelm et al. 2008	Van Zelm R., Huijbregts M. A. J., Den Hollander H. A., Van Jaarsveld H. A., Sauter F. J., Struijs J., Van Wijnen H. J. and Van de Meent D. (2008) European characterisation factors for human health damage of PM10 and ozone in life cycle impact assessment. In: Atmos Environ, 42, pp. 441-453.
Werner 2017	Werner F. (2017) Background report for the life cycle inventories of wood and wood based products for updates of ecoinvent 2.2. Werner Environment & Development, Zürich, CH.
WMO 2015	WMO (2015) Scientific Assessment of Ozone Depletion: 2014. World Meteorological Organisation, Geneva, CH.

NAUE GmbH & Co. KG
Gewerbestr. 2
32339 Espelkamp
Germany

Phone +49 5743 41-0
Fax +49 5743 41-240
info@naue.com
www.naue.com