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To whom it may concern

Uster, 23. July 2026

Extension of Validity of EPDs of Naue products to December 2028

Dear Sir or Madam,

according to Mr. Henning Ehrenberg, Naue GmbH & Co. KG, the production processes at Naue have not changed since the last edition of the Group EPDs established by treeze Ltd., published in 2024. The only change is that energy use has started to switch and will continue to be gradually converted to renewable energy.

This change would result in lower environmental impacts compared to those published. Hence, the last edition of the Group EPDs established by treeze Ltd. can be considered conservative in terms of environmental impacts per declared unit.

Based on this information, its assessment as well as the key characteristics of these EPDs, I confirm that their **validity** can be extended by three years until **December 2028**.

This belongs to:

- EPD-Bentofix, 16.07.2024
- EPD-CARBOFOL, 16.07.2024
- EPD-Secudrain, 16.07.2024
- EPD-Secugrid PET and Secugrid PP, 16.07.2024
- EPD-Secumat, 16.07.2024
- EPD-Secutex, 16.07.2024
- EPD-Secutex H 16.07.2024

Thank you very much for your attention to this matter.

R. Frischknecht

Dr. Rolf Frischknecht
Owner and Senior consultant

Environmental Product Declaration of CARBOFOL®

Author
Rolf Frischknecht

Uster, 16 July 2024

Client
Naue GmbH & Co. KG

Imprint

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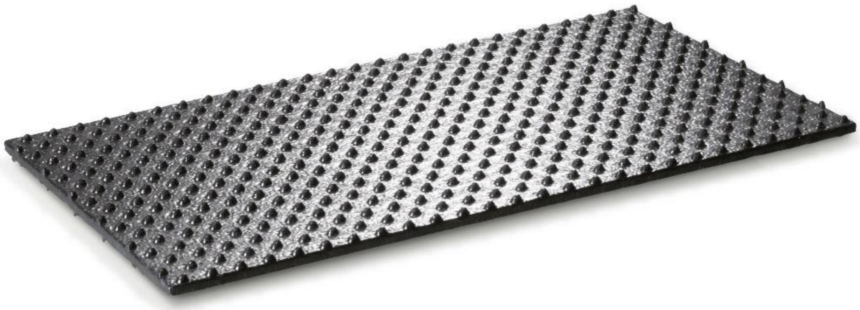
Version	EPD-CARBOFOL.docx, 16.07.2024

Environmental Product Declaration CARBOFOL®



Declaration holder

Naue GmbH & Co. KG
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Declared product:

CARBOFOL®, geomembranes for sealing

Data calculation by

treeze Ltd.
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Uston, September 2023

Programme Operator	Naue GmbH & Co. KG
Date of publication	16 July 2024
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 stand standard EN 15804:2012+A2:2019 (EN 15804 2019) and IES product category rules (IES 2018). The investigated products are the Naue geomembranes CARBOFOL® intended for the use many fields of civil engineering including landfill engineering and hydraulic engineering.

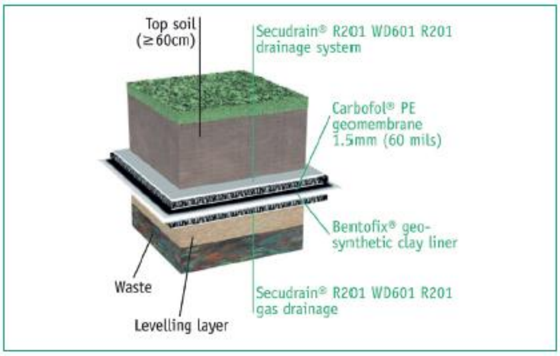
This EPD is a revision and extension of a work done in 2017 for the same kind of geosynthetics (NAUE 2017a). In comparison to 2017, the data are evaluated based on new background inventory where available. Furthermore, in this revision also the "end of life stage" (C1 – C4) is evaluated.

2 Product

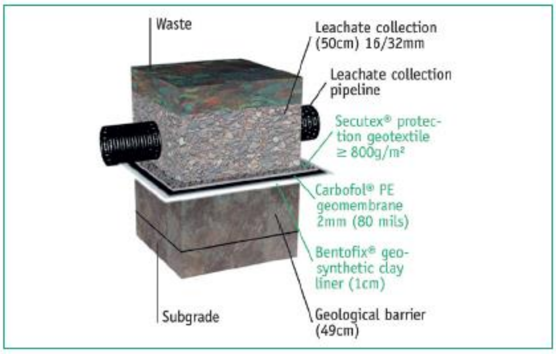
2.1 Description and Application

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 demands are based on the annual production of CARBOFOL® and does not reflect a specific product but the product family. The classification number according to the UN CPC classification system is 36950.

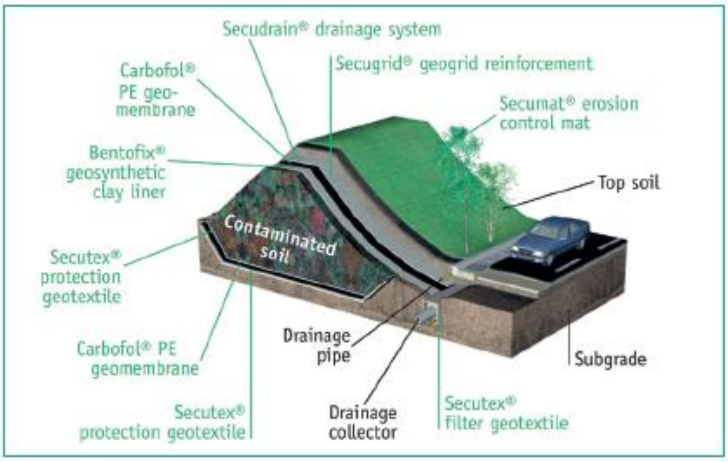
CARBOFOL®geosynthetics provide a complete seal against even the most toxic substances and are installed as a component of landfill base seals as well as caps CARBOFOL® protects groundwater from contamination. Even the strictest regulations and controls for the storage, filling, handling, manufacturing, 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.



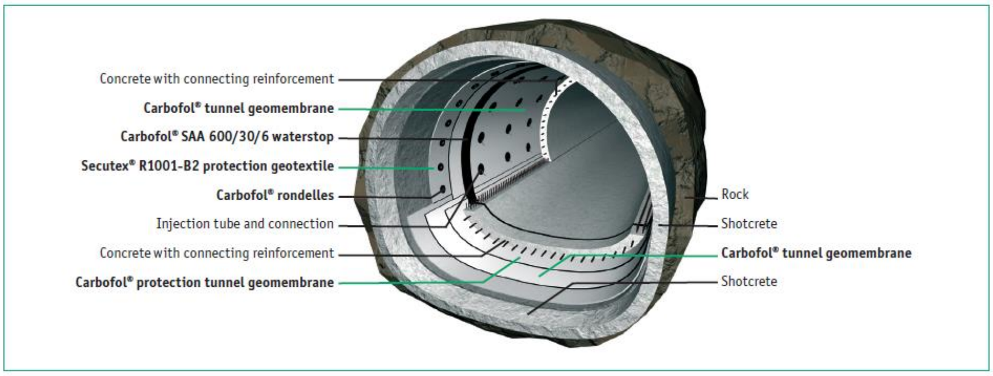
CARBOFOL®- landfill capping system



CARBOFOL®- landfill base lining system



CARBOFOL®- Encapsulation of contaminated soil



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

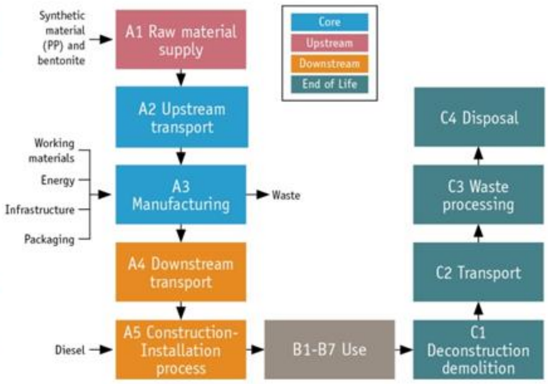


Fig. 2.1 Graphical overview of the life cycle stages covered by the EPD of geosynthetics

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. 2.1.

2.3 Upstream 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 production site by lorry only. The average shipping distances for HDPE and Carbon Black are 709 km and 470 km, respectively.

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.

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 2.47 MJ/m^2.

Tab. 2.1 Specific raw material, working material and energy consumption, wastes produced and infrastructure requirements per square meter of average geomembrane of the product family CARBOFOL®

Specific material consumption	Specific material and energy use per m^2	Unit	Carbofol®
Production volume and reference year	Annual production volume	tons	*
	Annual production volume	m^2	*
	Reference year		2019
	Mass per unit area	g/m^2	1'703
A1 Raw material	Recyclingsmaterial	g/m^2	105.2
	Polyethlyen (HDPE)	g/m^2	1'609.6
A2 Upstream transport	Lorry, 25 tons	tkm/m^2	1.11E+00
A3 Manufacturing (working material and energy consumption)	**Working material**		
	Tap water	kg/m^2	1.17E-01
	Lubricating oil	kg/m^2	4.82E-05
	Packaging		
	Paper case / cardboard	kg/m^2	2.42E-02
	LLDPE (Packaging)	kg/m^2	2.18E-04
	PVC	kg/m^2	1.18E-02

Specific material consumption	Specific material and energy use per m²	Unit	Carbofol®
	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

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

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 10.1 MJ/m².

2.8 Transport to product's waste processing (C2)

The end-of-life transports (C2) considers the transportation of the geosynthetics to a recycling site or disposal. On average, CARBOFOL® is transported 48 km 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 pretreatment, 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 1 m^2 of geomembrane of the product family CARBOFOL® with an average mass per unit area of 1’703 g/m^2.

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).

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 m^2 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 2016b), wood products (Werner 2017), aluminium (Stolz & Frischknecht 2016a) 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 freashwater 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[1]: Abiotic depletion potential for non-fossil resources (ADP-minerals&metals), CML 2002 (van Oers et al. 2002)
- Depletion of abiotic resources – fossil fuels[1]: Abiotic depletion potential for fossil resources (ADP-fossil), CML 2002 (van Oers et al. 2002)

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[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 experienced with the indicator.

- Water use[1]: 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[2]: 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 effects[1]: Potential Comparative Toxic Unit for humans (HTP-c), USEtox model (DG-JRC 2015)
- Human toxicity, non-cancer effects[1]: Potential Comparative Toxic Unit for humans (HTP-nc), USEtox model (DG-JRC 2015)
- Land use related impacts / soil quality[1]: 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

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[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.

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 (22'500 kg/m^2), inert material landfill (22'500 kg/m^2), sanitary landfill (20'000 kg/m^2) and residual material landfill (16'000 kg/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, PP and HDPE sold to the recycling company. The share of the waste for HDPE is 0.67 % 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.

4.1 Life cycle impact assessment results

Tab. 4.1 Environmental impact caused by the production of 1 sqm of the average CARBOFOL®

Environmental Impact 1 m² CARBOFOL 1703 g/m²	Unit	A1 Raw material	A2 Upstream transport	A3 Manufacturing	A4 Downstream transport	A5 Construction and installation	C1 Deconstruction	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)	mol 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 P-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	mol 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	m³ world eq. deprived	1.23E-01	3.37E-03	6.40E-02	5.57E-03	2.96E-03	1.21E-02	2.48E-04	4.66E-03
Particulate matter emissions	disease incidence	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

Tab. 4.2 Cumulative energy demand and energy use caused by the production of 1 sqm of the average CARBOFOL®

Energy Demand 1 m² Carbofol 1703 g/m²	Unit	A1 Raw material	A2 Upstream transport	A3 Manufacturing	A4 Downstream transport	A5 Construction and installation	C1 Deconstruction	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

Tab. 4.3 Material use and waste flows causes by the production of 1 sqm of the average CARBOFOL®

Material Use 1 m² Carbofol 1703 g/m²	Unit	A1 Raw material	A2 Upstream transport	A3 Manufacturing	A4 Downstream transport	A5 Construction and installation	C1 Deconstruction	C2 End-of-Life transport	C4 Disposal
Use of net fresh water	m³	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

4.2 Relative contribution of life cycle stages

Fig. 4.1 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, Photochemical 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 2017b) and for comparison purposes, the end of life stage C is not included in Fig. 4.1.

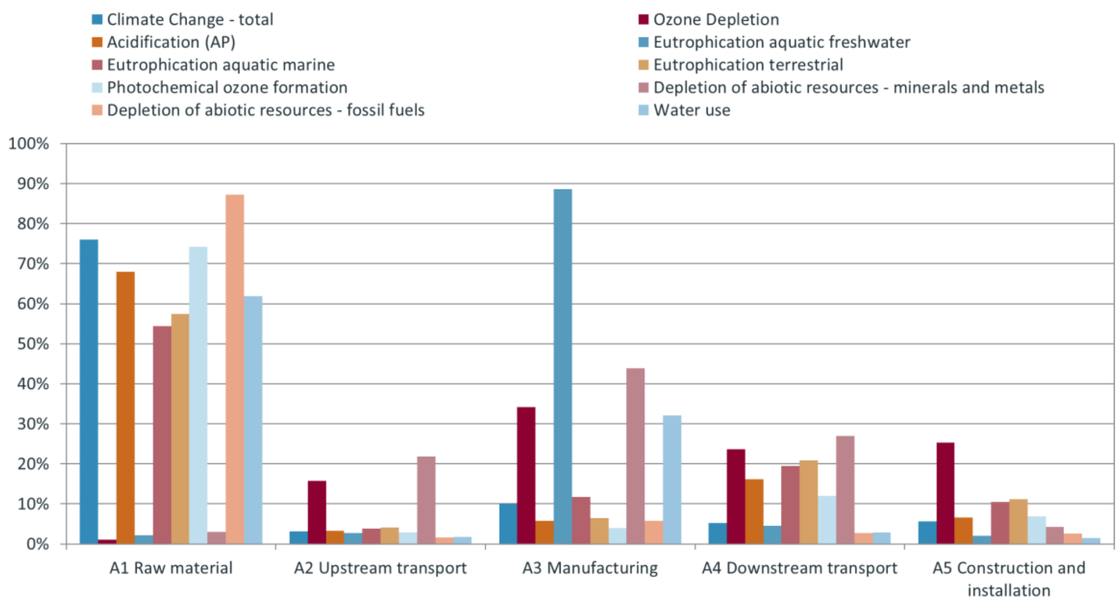

Fig. 4.1 Relative contribution of the different life cycle stages (A1 – A5) to the total impact of the product and construction process stage A of CARBOFOL®

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 component. 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 Environmental impacts according to the NMD method

The following table and figure is an extension to the Environmental Product Declaration of CARBOFOL®, published by Naue GmbH & Co. KG in 2021 (EPD-NAUE-CF-001-ref2 2017).

The potential benefits and loads are due to district heat and electricity by MSWI of 80 % of the geosynthetic materials. 10 % of the material is being recycled at end of life. This share corresponds to the amount used in production.

Tab. 5.1 Environmental impacts (EN 15804:2012+A2:2019) caused by the production and disposal of 1 sqm of the average CARBOFOL®

Environmental Impact 1 m² Carbofol® 1703 g/m²	Unit	A1 Raw material	A2 Upstream transport	A3 Manufacturing	A4 Downstream transport	A5 Construction and installation	C1 Deconstruction	C2 End-of-Life transport	C4 Disposal	D benefits and loads beyond the system boundary
Climate Change - total	kg CO2-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	-1.87E+00
Climate change - Fossil	kg CO2-eq.	3.40E+00	1.39E-01	4.87E-01	2.36E-01	2.53E-01	1.03E+00	1.02E-02	4.15E+00	-1.87E+00
Climate change - Biogenic	kg CO2-eq.	2.68E-02	-2.27E-05	-3.07E-02	-2.59E-05	-1.90E-05	-7.76E-05	-1.66E-06	1.02E-04	-3.77E-04
Climate change - Land use and LU change	kg CO2-eq.	1.43E-06	9.30E-06	1.33E-04	1.80E-05	6.97E-06	2.84E-05	6.82E-07	2.59E-06	-5.85E-04
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	-1.94E-07
Acidification (AP)	mol 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	-4.88E-03
Eutrophication aquatic freshwater	kg P-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	-8.64E-05
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	-7.12E-04
Eutrophication terrestrial	mol 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	-7.92E-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	-2.54E-03
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	-2.30E-07
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	-3.15E+01
Water use	m3 deprived	1.23E-01	3.37E-03	6.40E-02	5.57E-03	2.96E-03	1.21E-02	2.48E-04	4.66E-03	-9.28E-02
Particulate matter emissions	dis. incid.	1.23E-07	1.02E-08	8.42E-09	1.45E-08	6.26E-09	2.55E-08	7.50E-10	2.24E-09	-1.46E-08
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	-2.42E-01
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	-8.35E+00
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	-2.40E-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	-6.73E-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	-1.11E+00

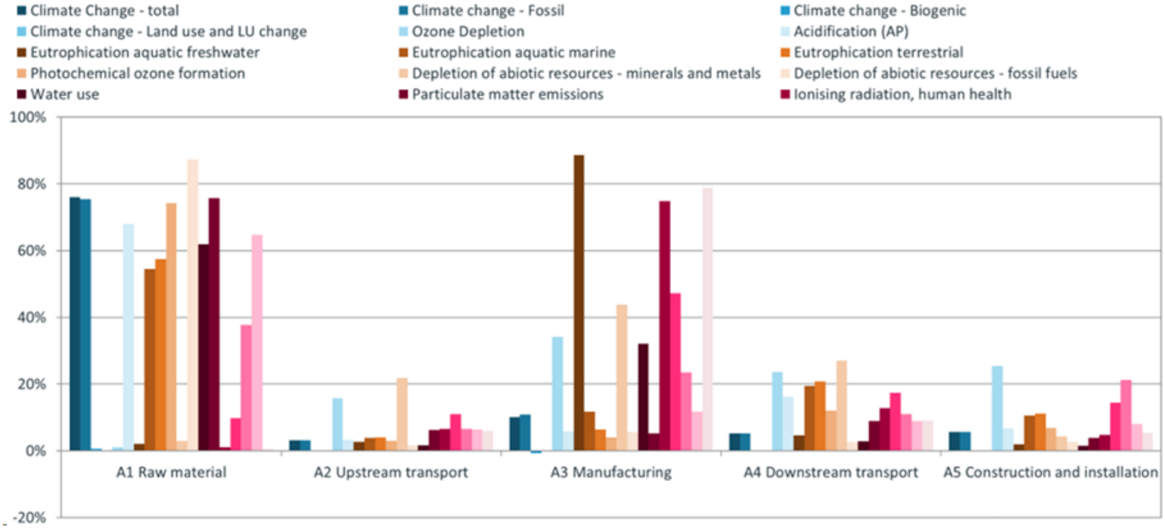

Fig. 5.1 Relative contribution of the different life cycle stages (A1 – A5) to the total impact of the product and construction process stage A of CARBOFOL®

6 Milieukostenindicator, The Netherlands

Tab. 6.1 Environmental impacts (EN 15804:2012+A1:2013) caused by the production of 1 sqm of the average CARBOFOL®

Environmental Impact 1 m^2 Carbofol® 1703 g/m^2	Unit	A1 Raw material	A2 Upstream transport	A3 Manufacturing	A4 Downstream transport	A5 Construction and installation	C1 Deconstruction	C2 End-of-Life transport	C4 Disposal	D Benefits and loads
Abiotic depletion	kg Sb eq	6.44E-08	3.26E-07	6.63E-07	4.05E-07	6.45E-08	2.63E-07	2.40E-08	3.16E-08	-2.48E-07
Abiotic depletion (fossil fuels)	kg Sb eq	5.36E-02	1.00E-03	3.52E-03	1.65E-03	1.64E-03	6.67E-03	7.34E-05	3.02E-04	-1.43E-02
Global warming (GWP100a)	kg CO2 eq	3.22E+00	1.37E-01	4.81E-01	2.33E-01	2.50E-01	1.02E+00	1.01E-02	4.15E+00	-1.84E+00
Ozone layer depletion (ODP)	kg CFC-11 eq	4.46E-10	6.87E-09	1.84E-08	1.01E-08	9.53E-09	3.88E-08	5.04E-10	4.12E-09	-1.76E-07
Photochemical oxidation	kg C2H4 eq	9.96E-04	2.50E-05	4.57E-05	7.78E-05	4.68E-05	1.91E-04	1.83E-06	9.57E-06	-2.30E-04
Acidification	kg SO2 eq	1.05E-02	4.88E-04	8.64E-04	2.38E-03	9.38E-04	3.83E-03	3.58E-05	3.81E-04	-4.13E-03
Eutrophication	kg PO4--- eq	6.95E-04	7.53E-05	4.28E-04	2.91E-04	1.68E-04	6.84E-04	5.52E-06	1.29E-04	-5.28E-04
Human toxicity	kg 1,4-DB eq	5.46E-02	4.50E-02	4.94E-02	7.84E-02	2.65E-02	1.08E-01	3.30E-03	1.08E-01	-1.15E-01
Fresh water aquatic ecotox.	kg 1,4-DB eq	4.77E-03	1.73E-03	2.37E-03	2.75E-03	1.85E-03	7.56E-03	1.27E-04	4.84E-02	-3.84E-03
Marine aquatic ecotoxicity	kg 1,4-DB eq	1.28E+02	1.45E+01	1.49E+02	3.16E+01	1.36E+01	5.54E+01	1.07E+00	7.75E+01	-4.74E+02
Terrestrial ecotoxicity	kg 1,4-DB eq	1.55E-04	2.93E-04	1.08E-03	4.80E-04	3.43E-04	1.40E-03	2.15E-05	1.50E-04	-9.92E-04

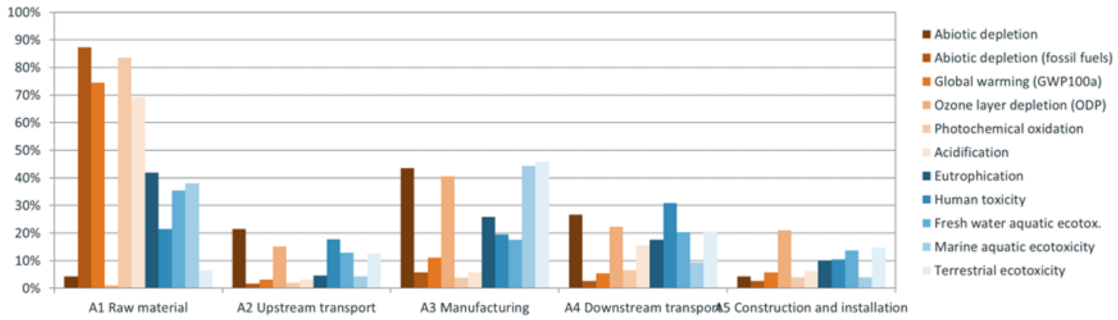

Fig. 6.1 Relative contribution of the different life cycle stages (A1 – A5) to the total environmental impacts of the product and construction process stage A of CARBOFOL®

Tab. 6.2 Environmental external costs (in EURO) caused by the production and disposal of 1 sqm of the average CARBOFOL®

NMD Bepalingsmethode, in EURO 1 m^2 Carbofol® 1703 g/m^2	A1 Raw material	A2 Upstream transport	A3 Manufacturing	A4 Downstream transport	A5 Construction and installation	C1 Deconstruction	C2 End-of-Life transport	C4 Disposal	D Benefits and Loads	Total
Abiotic depletion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion (fossil fuels)	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Global warming (GWP100a)	0.16	0.01	0.02	0.01	0.01	0.05	0.00	0.21	-0.09	0.47
Ozone layer depletion (ODP)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Photochemical oxidation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acidification	0.04	0.00	0.00	0.01	0.00	0.02	0.00	0.00	-0.02	0.08
Eutrophication	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02
Human toxicity	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	-0.01	0.04
Fresh water aquatic ecotox.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Marine aquatic ecotoxicity	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01	-0.05	0.05
Terrestrial ecotoxicity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.24	0.02	0.05	0.03	0.02	0.09	0.00	0.23	-0.17	0.68

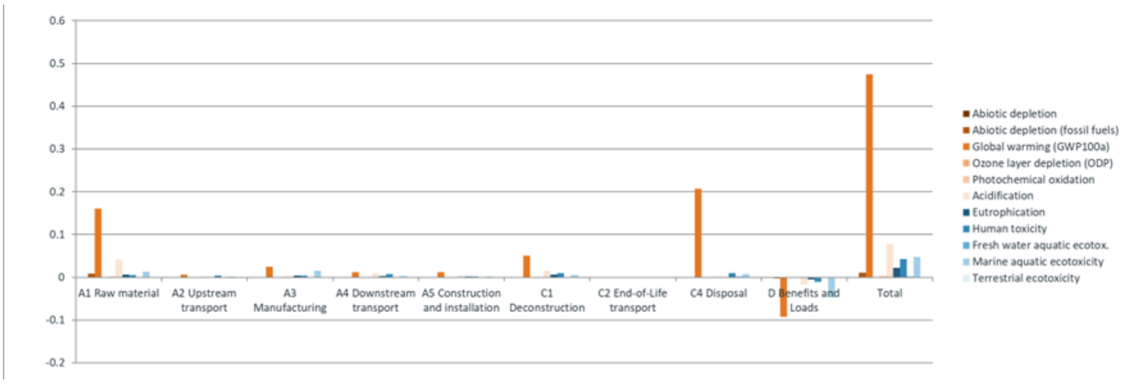

Fig. 6.2 Environmental external costs of the different life cycle stages (A1 – A5, C1 – C4, D, and Total, excluding D) of the manufacture and disposal of 1 sqm average CARBOFOL®

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