ENVIRONMENTAL PRODUCT DECLARATION

# MARMOLEUM FR2

FORBO FLOORING SYSTEMS
RESILIENT LINOLEUM FLOOR COVERING

Marmoleum FR2
Colour 3403 "Asian tiger"

FLOORING SYSTEMS

Marmoleum the most globally used brand of linoleum has been manufactured by Forbo for more than 150 years. Marmoleum is produced having low environmental impacts as a result of the combination of natural renewable materials and high recycle content.

Forbo was the first flooring manufacturer to publish a complete Life Cycle Assessment (LCA) report verified by CML in 2000.In addition Forbo is now to publish Environmental Product Declarations (EPD) for all products including full LCA reports. This EPD is using all recognized flooring Product Category Rules and is including additional information to show the impacts on human health and eco-toxicity. By offering the complete story we hope that our stakeholders will be able to use this document as a tool that will translate the environmental performance of Marmoleum into the true value and benefits to all our customers and stakeholders alike.

For more information visit;
www.forbo-flooring.com

CERTIFIED
ENVIRONMENTAL PRODUCT DECLARATION
UL.COM/EPD

FLOORING SYSTEMS

**Marmoleum FR2**
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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

| | |
|---|---|
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| DECLARATION HOLDER | Forbo Flooring B.V.<br>Industrieweg 12<br>P.O. Box 13<br>NL-1560 AA Krommenie |
| DECLARATION NUMBER | 4789275679.140.1 |
| DECLARED PRODUCT | Marmoleum FR2 2.5mm Resilient Linoleum Floor Covering |
| REFERENCE PCR | EN 16810 : Resilient, Textileand Laminate floor coverings – Environmental product declarations – Product category rules |
| DATE OF ISSUE | January 1, 2020 |
| PERIOD OF VALIDITY | 5 Years |
| CONTENTS OF THE DECLARATION | Product definition and information about building physics<br>Information about basic material and the material's origin<br>Description of the product's manufacture<br>Indication of product processing<br>Information about the in-use conditions<br>Life cycle assessment results<br>Testing results and verifications |

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

This EPD conforms with EN 15804

# Product Definition

## Product Classification and description

Marmoleum is a resilient floor covering made from natural raw materials making it a preferable ecological and durable floor covering with a beautiful and colorful design. The key raw materials include linseed oil, which comes from the flax plant seeds, gum rosin from pine trees, recycled wood waste of wood from controlled forests, limestone and jute from the jute plant which is used for the backing. Because of the use of natural raw materials Marmoleum can be composted in an appropriate composting facility.
Linoleum is produced by Forbo Flooring for more than 150 years and our well-known brand Marmoleum is sold worldwide.
This declaration refers to Marmoleum FR2 sheet of 2.5 mm nominal thickness covering a broad range of designs and colors :
Concrete, Fresco, Real, Vivace, Walton Cirrus

Depending on color variations of these designs the recycled content can vary from 40 to 44%

Marmoleum FR2 is build up in 3 layers as illustrated in figure 1.

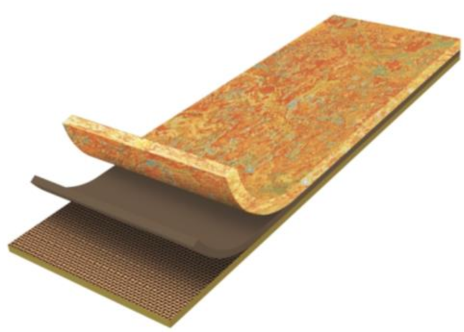


*Figure 1: Illustration of Marmoleum FR2*

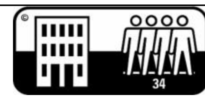
These two layers form one homogeneous product by the cross linking bondings formed during the oxidative curing process :

1. **Surface layer:** This layer gives Marmoleum its design and color. After finishing the product at the trimming department a factory finish is applied to protect the surface layer.
2. **Intermediate layer:** This layer is calendared on the jute backing and contains reused Linoleum.
3. **Backing:** The backing is woven jute.

The declaration refers to the declared/functional unit of 1m² installed flooring product.

## Range of application

Marmoleum is to be installed in the following use areas defined in EN–ISO 10874:

| Area of application | **Commercial** |
|---|---|
| **Marmoleum FR2 (2½ mm)** |  |

## Product Standard

The products considered in this EPD have the following technical specifications for fire testing :

- Meets or exceeds Class 1 when tested in accordance with ASTM E 648/NFPA 253, Standard Test Method for Critical Radiant Flux.
- Meets 450 or less when tested in accordance with ASTM E 662/NFPA 258, Standard Test Method for Smoke Density.
- Class HL3 when tested in accordance with EN 45545-2, Railway applications - Fire protection on railway vehicles - Part 2: Requirements for fire behavior of materials and components
- Class 1a when tested in accordance with BS6853, fire test to railway components, code of practice for fire precautions in the design and construction of passenger carrying trains

## Accreditation

- ISO 9001 Quality Management System
- ISO 14001 Environmental Management System
- ISO 45001 Occupational Health and Safety Management Systems
- SA 8000 Social Accountability standard

## Delivery Status

*Table 1: Specification of delivered product*

| Characteristics | Nominal Value | Unit |
|---|---|---|
| Product thickness | 2.5 | mm |
| Product Weight 2.5 mm | 2900 | $g/m^2$ |
| Rolls Width<br>Length | 2.00<br>< 32 | meter |

## Material Content

### Material Content of the Product

*Table 2: Composition of Marmoleum FR2*

| Component | Material | Availability | Amount [%] | Origin |
|---|---|---|---|---|
| **Binder** | Linseed oil<br>Gum rosin<br>Tall oil | Bio based crop<br>Bio based crop<br>Bio based waste product from paper Industry | 18<br>2<br>9 | USA/Canada/Europe<br>Indonesia/China<br>USA |
| **Filler** | Wood flour<br>Alumina trihydrate<br>Reused Marmoleum<br>Calcium Carbonate | Bio based waste product from wood processing<br>Limited mineral<br><br>Abundant mineral | 22<br>25<br>9<br>3 | Germany<br>Germany<br>Internal<br>Germany |
| **Pigment** | Titanium dioxide<br>Various other pigments | Limited mineral<br>Limited mineral | 2<br>0.5 | Global<br>Global |
| **Backing** | Jute | Bio based crop | 9 | India/Bangladesh |
| **Finish** | Lacquer | | 0.5 | Netherlands |

### Production of Main Materials

**Linseed oil** : Linseed oil is obtained by pressing the seeds of the flax plant. After filtering a clear golden yellow liquid remains.
**Gum rosin** :  Rosin is obtained by wounding pine trees. The crude gum is collected and is separated into turpentine and rosin by distillation.
**Tall oil** : Tall oil is a post industrial waste product coming from the paper industry and is consisting of vegetable oil and rosin.
**Wood flour** : Postindustrial bio based soft wood waste from the wood industry, which is milled into flour.
**Alumina trihydrate:** Fire retardant filler obtained by extracting aluminium hydroxide from Bauxite which is naturally occurring in the Earth's surface. Imparts fire retardance of Marmoleum FR2
**Calcium carbonate** : An abundant mineral found in all parts of the world as the chief substance in rocks (i.e., marble and limestone). It can be ground to varying particle sizes and is widely used as filler.
**Titanium dioxide** : A white pigment produced from the mineral rutile, a naturally occurring form of titanium dioxide. The production of the pigment is a large-scale chemical process
**Various other pigments** : The vast majority of the used color pigments are iron oxide based.
**Jute** : Jute fiber is extracted from the stem of the jute plant by floating it in water. For yarn production fiber bands are obtained by carding, stretching, spinning, warping and sizing. Finally the yarn is woven.
**Lacquer** : The factory applied lacquer – Topshield 2 – is a waterborne UV cured double layer factory coating – acrylate hybrid dispersion.

## Production of the Floor Covering

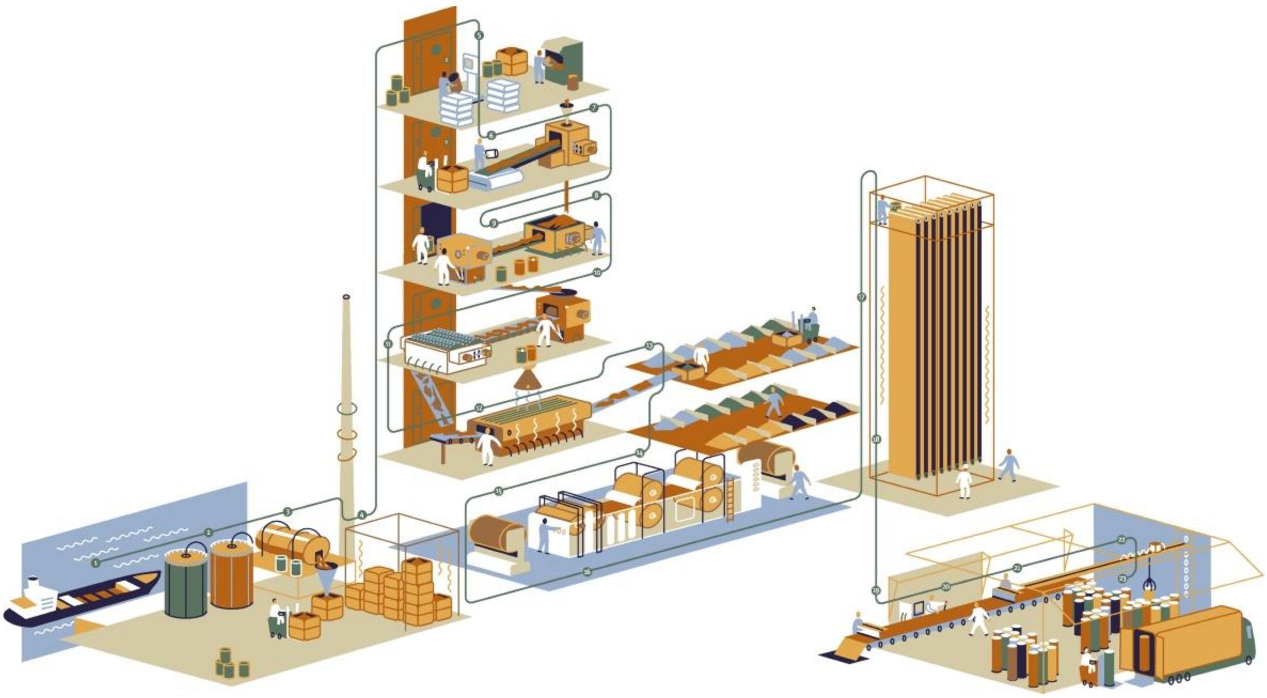


*Figure 2: Illustration of the Production process*

Marmoleum is produced in several stages starting with the oxidation of linseed oil mixed with tall oil and rosin. With the influence of oxygen from the atmosphere a tough sticky material is obtained called linoleum cement. The linoleum cement is stored in containers for a few days for further reaction and after this it is mixed with wood flour, calcium carbonate, reused waste (if applicable), titanium dioxide and pigments. This mixture is calendared on a jute substrate and stored in drying rooms, to cure till the required hardness is reached. After approximately 14 days the material is taken out from the drying room to the trimming department where the factory finish is applied on the surface of the product and the end inspection is done. Finally the edges are trimmed and the sheet is cut to length into rolls of approximately 32 meter. The trimmings and the rejected product are reused.

### Health, Safety and Environmental Aspects during Production

- ISO 14001 Environmental Management System
- ISO 45001 Occupational Health and Safety Management Systems
- SA 8000 Social Accountability standard

### Production Waste

Rejected material and the cuttings of the trimming stage are being reused in the manufacturing process.
Packaging materials are being collected separately and externally recycled.

## Delivery and Installation of the Floor Covering

### Delivery

A worldwide distribution by truck and container ship is considered. On average every square meter of Marmoleum is transported as follows:

| | |
|---|---|
| ○ Transport distance 40 t truck | 634 km |
| ○ Transport distance 7.5t truck (Fine distribution) | 162 km |
| ○ Capacity utilization trucks (including empty runs) | 85 % |
| ○ Transport distance Ocean ship | 2290 km |
| ○ Capacity utilization Ocean ship | 48% |

### Installation

Because of the specific techniques used during the installation of Marmoleum an average of 6% of the material is cut off as installation waste. For installation of Marmoleum on the floor an average scenario has been modeled (assuming 0.280 kg/m2 of adhesive is required).
Waste during the installation process may be recycled as floor covering through the manufacturers' facilities or thermally recycled in a waste incineration plant. Since the major part of Marmoleum is sold in Europe the European electricity grid mix is used in the calculations for the energy recovery during incineration.

## Health, Safety and Environmental Aspects during Installation

Forbo flooring recommends to use a low emission EC1 adhesive for installing Marmoleum.

### Waste

Waste during the installation process may be recycled as floor covering through the manufacturers' facilities or thermally recycled in a waste incineration plant. Since the major part of Marmoleum is sold in Europe the European electricity grid mix is used in the calculations for the energy recovery during incineration.

### Packaging

Cardboard tubes and packaging paper can be collected separately and should be used in a local recycling process. In the calculation model 100% incineration is taken into account for which there is a credit received.

## Use stage

The service lifetime of a floor covering for a certain application on a floor is too widespread to give one common number. For this EPD model the reference service lifetime (RSL) is set to one year. This means that all impacts for the use phase are based on the cleaning and maintenance model for one year. Depending on the area of use, the technical lifetime advised by the manufacturer and the estimated time on the floor by the customer, the service lifetime can be determined. The use phase impacts should be calculated with the foreseen service life to arrive at the total environmental impact.

### Cleaning and Maintenance

| Level of use | Cleaning Process | Cleaning Frequency | Consumption of energy and resources |
|---|---|---|---|
| Commercial/Residential/Industrial | Vacuuming | Twice a week | Electricity |
| | Damp mopping | Once a week | Hot water<br>Neutral detergent |

For the calculations the following cleaning regime is considered:

- Dry cleaning with a 1.5 kW vacuum cleaner for 0.21 min/m$^2$, twice a week. This equates to 0.55 kWh/m$^2$*year.
- Once a week wet cleaning with 0.062 l/m$^2$ water and 0.0008 kg/m$^2$ detergent. This result in the use of 3.224 l/m$^2$*year water and 0.04 kg/m$^2$*year detergent. The wet cleaning takes place without power machine usage. Waste water treatment of the arising waste water from cleaning is considered.

The cleaning regime that is recommended in practice will be highly dependent on the use of the premises where the floor covering is installed. In high traffic areas more frequent cleaning will be needed compared to areas where there is low traffic. The use of an entrance mat of at least four steps will reduce the cleaning frequency.
The cleaning regime used in the calculations is suitable for high traffic areas.

### Prevention of Structural Damage

All newly laid floor covering should be covered and protected with a suitable non-staining protective covering if other building activities are still in progress. Use protective feet on chairs and tables to reduce scratching. Castor wheels should be suitable for resilient floor coverings.

### Health Aspects during Usage

Low VOC cleaning materials are available for use in maintaining Marmoleum FR2.

## End of Life

The deconstruction of installed Marmoleum from the floor is done mechanically and the electrical energy needed for this is estimated to be 0.03 kWh/sqm. This amount of energy is taken into account for the calculations.
For the end of life stage no landfilling is taken into account, since the vast majority of the countries in which Marmoleum is sold are having a non landfill policy. Because of the high calorific value of Marmoleum the incineration is very profitable as a waste to energy conversion.

## Life Cycle Assessment

A full Life Cycle Assessment has bee carried out according to ISO 14040 and ISO 14044.

The following Life Cycle Stages are assessed :

- A1-3 : Product Stage (Raw material acquisition, transportation to Manufacturing and Manufacturing)
- A4-5 : Construction process stage (Transport Gate to User, installation flooring)
- B2 : Use Stage (Maintenance of the floor)
- C1-4 : End of Life Stage (Deconstruction, transport, waste processing, Disposal)
- D : Benefits and loads beyond the system boundary (Reuse, recovery, recycling potential)

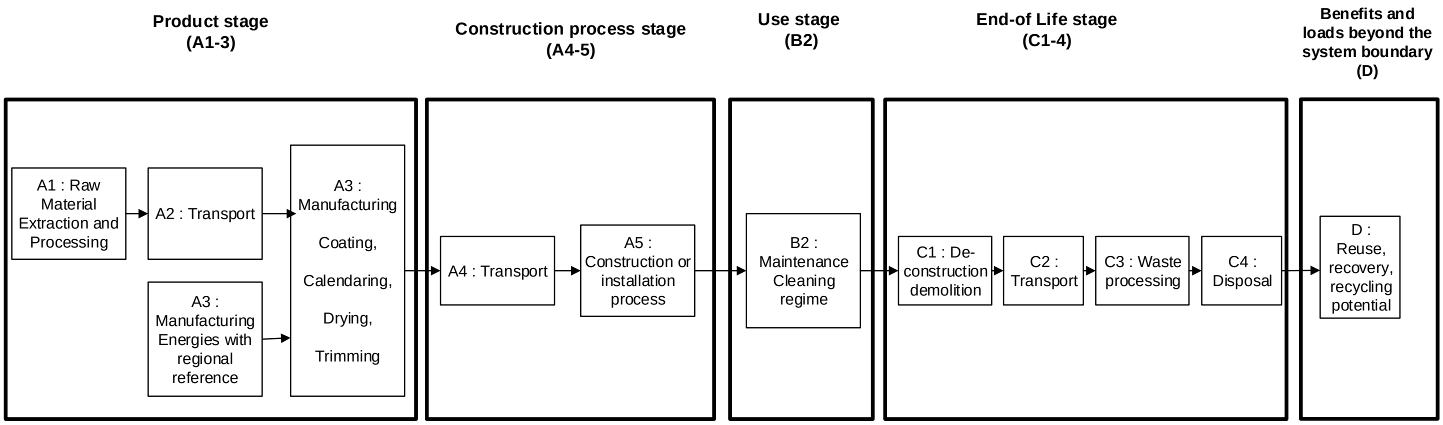



*Figure 3: Flow chart of the Life Cycle Assessment*

Comparisons of different floor coverings are only allowed, where EN 15804 consistent and/or preverified background data and EN 15804 consistent calculation methods and database versions are used and when the building context is taken into account, i.e. on the basis of the same use-classification (EN ISO 10874), same service life and comparable assumptions for the end of life.

### Description of the Declared Functional Unit

The functional unit is one square meter of installed product and the use stage is considered for one year of service life.

### Cut off Criteria

The cut-off criteria shall be 1% of renewable and non-renewable primary energy usage and 1% of the total mass of the unit process. The total neglected input flows per module shall be a maximum of 5% of energy usage and mass.

In practice, in this assessment, all data from the production data acquisition are considered, i.e. all raw materials used as per formulation, use of water, electricity and other fuels, the required packaging materials, and all direct production waste. Transport data on all considered inputs and output material are also considered.

### Allocations

In the present study some allocations have been made. Detailed explanations can be found in the chapters below.

## Co-product allocation

No co-product allocation occurs in the product system.

## Allocation of multi-input processes

The Production and End of Life stage include incineration plants. In these processes different products are treated together within a process. The allocation procedures followed in these cases are based on a physical classification of the mass flows or calorific values.

Credits from energy substitution are allocated to the production stage, because the gained energy from energy substitution is lower than the energy input in this stage. The same quality of energy is considered.

## Allocation procedure of reuse, recycling and recovery

The installation waste and end of life waste is fed into incineration processes. Incineration processes include cogeneration processes which give thermal and power energy as outputs. It is assumed that this recovered energy offsets that produced by the European average grid mix and thermal energy generation from natural gas.

## Description of the allocation processes in the LCA report

The description of allocation rules in of this LCA report meets the requirements of the PCR.

## LCA Data

As a general rule, specific data derived from specific production processes or average data derived from specific production processes have been used as the first choice as a basis for calculating an EPD.

For life cycle modeling of the considered products, the GaBi 9 Software System for Life Cycle Engineering, developed by THINKSTEP AG has been used. All relevant LCA datasets are taken from the GaBi 9 software database. The datasets from the database GaBi are documented in the online documentation. To ensure comparability of results in the LCA, the basic data of GaBi database were used for energy, transportation and auxiliary materials.

## Data Quality

The requirements for data quality and LCA data correspond to the specifications of the PCR.

Foreground data are based on 1 year averaged data (year 2019). The reference ages of LCA datasets vary but are given in the table in the Appendix. The time period over which inputs to and outputs from the system is accounted for is 100 years from the year for which the data set is deemed representative. The technological LCA of the collected data reflects the physical reality of the declared product. The datasets are complete, conform to the system boundaries and the criteria for the exclusion of inputs and outputs and are geographical representative for the supply chain of Forbo flooring.

For life cycle modeling of the considered products the GaBi 9 Software System for Life Cycle Engineering, developed by THINKSTEP AG, is used. All relevant LCA datasets are taken from the GaBi 9 software database. The last revision of the used data sets took place within the last 10 years.

## System Boundaries

Production Stage includes provision of all materials, products and energy, packaging processing and its transport, as well as waste processing up to the end-of waste state or disposal of final residues during the product stage.

Transport and Installation Stage includes provision of all materials, products and energy, as well as waste processing up to the end-of-waste state or disposal of final residues during the construction stage. These information modules also include all impacts and aspects related to any losses during this construction stage (i.e. production, transport, and waste processing and disposal of the lost products and materials). For the transportation a worldwide distribution is considered.

Use Stage includes provision and transport of all materials, products and related energy and water use, as well as waste processing up to the end-of-waste state or disposal of final residues during this part of the use stage. These information modules also include all impacts and aspects related to the losses during this part of the use stage (i.e. production, transport, and waste processing and disposal of the lost products and materials).

End of Life Stage includes provision and all transports, provision of all materials, products and related energy and water use. It also includes any declared benefits and loads from net flows leaving the product system that have not been allocated as co-products and that have passed the end-of-waste state in the form of reuse, recovery and/or recycling potentials.

## Power mix

The selection of LCA data for the electricity generation is in line with the PCR.

The products are manufactured in Assendelft, the Netherlands. The GaBi 9 Hydropower dataset has therefore been used (reference year 2019). The energy supplier is providing Forbo with a certificate every year.

## $CO_2$-Certificates

No $CO_2$-certificates are considered in this study.

## Life Cycle Inventory Analysis

In table 3 the environmental impacts for one lifecycle are presented for Marmoleum FR2. In tables 4 the environmental impacts are presented for all the lifecycle stages.

Table 3: Results of the LCA – Environmental impacts one lifecycle (one year) – Marmoleum FR2

| Impact Category : CML 2001 – Jan. 2016 | Marmoleum FR2 | Unit |
|---|---|---|
| Global Warming Potential (GWP 100 years) | 5,88E+00 | kg CO2-Equiv. |
| Ozone Layer Depletion Potential (ODP. steady state) | 2,16E-08 | kg R11-Equiv. |
| Acidification Potential (AP) | 4,54E-02 | kg SO2-Equiv. |
| Eutrophication Potential (EP) | 1,11E-02 | kg Phosphate-Equiv. |
| Photochem. Ozone Creation Potential (POCP) | 1,72E-03 | kg Ethene-Equiv. |
| Abiotic Depletion Potential Elements (ADPE) | 3,00E-06 | kg Sb-Equiv. |
| Abiotic Depletion Potential Fossil (ADPF) | 6,68E+01 | [MJ] |

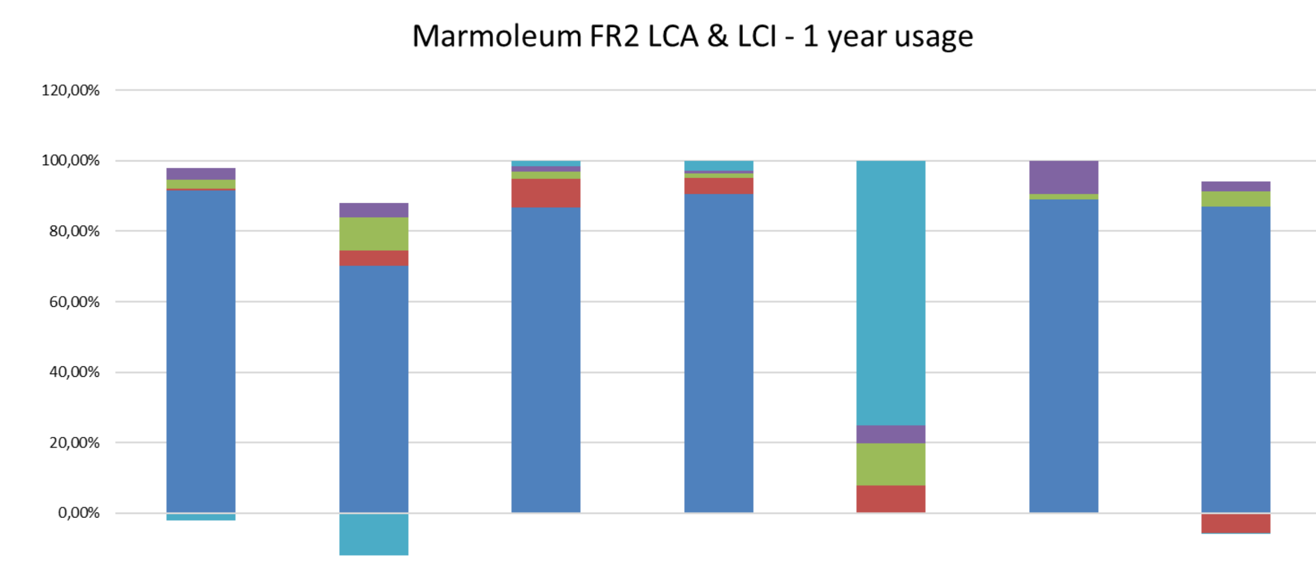
Table 4: Results of the LCA – Environmental impact for Marmoleum FR2 (one year)

| Impact Category : CML 2001 – Jan. 2016 | | Manufacturing | Installation | | Use (1yr) | End of Life | | | Credits |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **A1-3** | **A4** | **A5** | **B2** | **C1** | **C2** | **C3** | **D** |
| GWP | [kg $CO_2$-Eq.] | -7,49E-03 | 4,56E-01 | 7,16E-01 | 2,91E-01 | 2,23E-01 | 2,03E-02 | 5,21E+00 | -1,03E+00 |
| ODP | [kg CFC11-Eq.] | 1,92E-08 | 4,27E-17 | 3,33E-10 | 2,06E-09 | 6,26E-15 | 3,35E-18 | 9,51E-16 | -1,43E-14 |
| AP | [kg $SO_2$-Eq.] | 3,94E-02 | 3,70E-03 | 8,82E-04 | 7,48E-04 | 6,34E-04 | 4,93E-05 | 1,72E-03 | -1,75E-03 |
| EP | [kg $PO_4^{3-}$- Eq.] | 1,01E-02 | 4,99E-04 | 1,40E-04 | 9,43E-05 | 5,94E-05 | 1,23E-05 | 4,28E-04 | -1,89E-04 |
| POCP | [kg Ethen Eq.] | 1,70E-03 | -1,11E-04 | 8,22E-05 | 5,40E-05 | 4,03E-05 | -1,68E-05 | 1,10E-04 | -1,38E-04 |
| ADPE | [kg Sb Eq.] | 2,86E-06 | 1,68E-08 | 7,89E-08 | 1,03E-07 | 7,11E-08 | 1,56E-09 | 5,12E-08 | -1,87E-07 |
| ADPF | [MJ] | 6,19E+01 | 3,73E+00 | 8,27E+00 | 3,53E+00 | 2,40E+00 | 2,75E-01 | 1,31E+00 | -1,46E+01 |

GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophication potential; POCP = Formation potential of tropospheric ozone photochemical oxidants; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources

The relative contribution of each process stage to each impact category for Marmoleum FR2 is shown in figure 4.

Figure 4: relative contribution of each process stage to each impact category for Marmoleum FR2 for a one year usage.




| | Abiotic Depletion (Elements) | Abiotic Depletion (Fossil) | Acidification Potential | Eutrophication Potential | Global Warming Potential | Ozone Layer Depletion Potential | Photochem. Ozone Creation Potential |
|---|---|---|---|---|---|---|---|
| End of Life | -2,02% | -12,06% | 1,44% | 2,79% | 75,05% | 0,00% | -0,23% |
| Use | 3,30% | 4,01% | 1,65% | 0,85% | 4,94% | 9,54% | 2,77% |
| Installation | 2,53% | 9,39% | 1,94% | 1,26% | 12,15% | 1,54% | 4,21% |
| Transport | 0,54% | 4,24% | 8,15% | 4,48% | 7,74% | 0,00% | -5,69% |
| Production | 91,61% | 70,30% | 86,82% | 90,63% | -0,13% | 88,92% | 87,10% |

## Interpretation

The interpretation of the results has been carried out considering the assumptions and limitations declared in the EPD, both methodology- and data-related for a one year usage.

The LCA for GWP reflects the use of renewable raw materials for the production of Marmoleum (linseed oil and jute). Carbon dioxide, a greenhouse gas, is locked in from the atmosphere in the course of the plant growth via photosynthesis and stored during the use stage. This carbon dioxide is not released until the end of life when it is incinerated with energy recovery – this process accounts for the greatest emission of greenhouse gases in the life cycle of the product.
For the production stage of Marmoleum FR2 the uptake of CO2 is higher than the emission of greenhouse gasses resulting in a slightly negative life cycle stage.

In the other 6 impact categories (ODP, AP, EP, POCP, ADPE, ADPF) the production stage has the main contribution to the overall impact. For these categories the main contributor in the production stage is the raw material extraction and processing with a share of 60-100% of total impacts from the production stage.

Forbo declares in the EPD a worldwide distribution by truck (796 km) and container ship (2290 km). For this scenario the transport has a relevance of 4-11% in the impact categories GWP, AP, EP and ADPF.
The negative impact for POCP for the transportation stage is remarkable, but it is assumed that NO and CO reduces the accumulated ozone to NO2, CO2 and O2. This means, that high concentrations of ozone do not often occur near hydrocarbon emission sources. Higher ozone concentrations more commonly arise in areas of clean air, such as forests, where there is less NO and CO.

For GWP and ADPF the adhesive for the flooring installation has a significant impact. The LCA for the installation is based on an assumption of 280 g/m² adhesive.

The use stage is calculated for one year of service life time with a conservative scenario based on a cleaning regime suitable for high traffic areas. The electricity and detergent used to clean the floor are the main contributors for this life cycle stage.

Energy recovery from incineration and the respective energy substitution at the end of life results in a credit as reported in the End of Life stage.

## Resource use

In table 5 the parameters describing resource use are presented for all the lifecycle stages for a one year usage.

Table 5: Results of the LCA – Resource use for Marmoleum FR2 (one year)

| | | Manufacturing | Installation | | Use (1yr) | End of Life | | | Credits |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **A1-3** | **A4** | **A5** | **B2** | **C1** | **C2** | **C3** | **D** |
| PERE | [MJ] | 3,15E+01 | - | - | - | - | - | - | - |
| PERM | [MJ] | 3,95E+01 | - | - | - | - | - | - | - |
| PERT | [MJ] | 7,10E+01 | 1,52E-01 | 3,31E-01 | 1,68E+00 | 1,63E+00 | 1,60E-02 | 2,20E-01 | -3,72E+00 |
| PENRE | [MJ] | 4,89E+01 | - | - | - | - | - | - | - |
| PENRM | [MJ] | 1,63E+01 | - | - | - | - | - | - | - |
| PENRT | [MJ] | 6,52E+01 | 3,75E+00 | 8,45E+00 | 5,34E+00 | 4,04E+00 | 2,76E-01 | 1,51E+00 | -1,83E+01 |
| SM | [kg] | -5,99E-02 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| RSF | [MJ] | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| NRSF | [MJ] | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| FW | [m$^3$] | 6,24E-02 | 2,57E-04 | 2,12E-03 | 2,02E-03 | 1,92E-03 | 2,70E-05 | 1,19E-02 | -4,39E-03 |

PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water

## Waste categories and output flows

In table 6 other environmental information describing different waste categories and output flows are presented for all the lifecycle stages.

Table 6: Results of the LCA – Output flows and Waste categories for Marmoleum FR2 (one year)

| | | Manufacturing | Transport | Installation | Use (1yr) | End of Life/credits | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **A1-3** | **A4** | **A5** | **B2** | **C1** | **C2** | **C3** | **D** |
| HWD | [kg] | 4,11E-08 | 1,43E-07 | 3,41E-09 | 2,04E-09 | 1,93E-09 | 1,54E-08 | 1,08E-09 | -7,54E-09 |
| NHWD | [kg] | 3,18E-01 | 2,15E-04 | 5,77E-03 | 6,21E-03 | 2,94E-03 | 2,24E-05 | 3,66E-02 | -7,93E-03 |
| RWD | [kg] | 1,30E-03 | 4,89E-06 | 7,22E-05 | 6,93E-04 | 6,51E-04 | 3,74E-07 | 7,61E-05 | -1,49E-03 |
| CRU | [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 |
| MFR | [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 |
| MER | [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 |
| EE Power | [MJ] | 0,00E+00 | 0,00E+00 | 4,38E-01 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 5,93E+00 | 0,00E+00 |
| EE Thermal energy | [MJ] | 0,00E+00 | 0,00E+00 | 7,79E-01 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 1,05E+01 | 0,00E+00 |

HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; RWD = Radioactive waste disposed; CRU = Components for re-use; MFR = Materials for recycling; MER = Materials for energy recovery; EE = Exported energy per energy carrier

## Additional Environmental Information

To be fully transparant Forbo Flooring does not only want to declare the environmental impacts required in the PCR, but also the impacts on human health and eco-toxicity

### Toxicity

For this calculations the USEtoxTM model is used as being the globally recommended preferred model for characterization modelling of human and eco-toxic impacts in LCIA by the United Nations Environment Programme SETAC Life Cycle Initiative.

According to the "ILCD Handbook: Recommendations for Life Cycle Impact Assessment in the European context" the recommended characterization models and associated characterization factors are classified according to their quality into three levels:

- Level I (recommended and satisfactory),
- level II (recommended but in need of some improvements)
- level III (recommended, but to be applied with caution).

A mixed classification sometimes is related to the application of the classified method to different types of substances. USEtoxTM is classified as Level II / III, unlike for example the CML impact categories which are classified as Level I.

Table 7: Results of the LCA – Environmental impacts one lifecycle (one year) – Marmoleum FR2

| **Impact Category : USEtox** | **Marmoleum FR2** | **Unit** |
|---|---|---|
| Eco toxicity | 4,05E-03 | PAF m3.day |
| Human toxicity, cancer | 5,14E-10 | Cases |
| Human toxicity, non-canc. | 8,36E-11 | Cases |

In the following table the impacts are subdivided into the lifecycle stages.

Table 8: Results of the LCA – Environmental impact for Marmoleum FR2 (one year)

| Impact Category : USEtox | Unit | Production | Transport | Installation | Use (1yr) | End of Life |
|---|---|---|---|---|---|---|
| Eco toxicity | PAF m3.day | 2,23E-03 | 8,49E-04 | 8,44E-04 | 4,21E-04 | -2,97E-04 |
| Human toxicity, cancer | cases | 5,37E-10 | 9,53E-13 | 1,77E-11 | 3,01E-11 | -7,12E-11 |
| Human toxicity, non-canc. | cases | 2,91E-11 | 3,54E-13 | 5,45E-11 | 7,26E-13 | -1,02E-12 |

## Interpretation

The interpretation of the results has been carried out considering the assumptions and limitations declared in the EPD, both methodology- and data-related for a one year usage.

The Eco-toxicity is mostly dominated by the production stage in which the raw materials are having the biggest impact with a share of around 41%. The other main contributors in the production stage are the thermal energy and the packaging of the end product during manufacturing. Other main contributor of the total life cycle are the transport to the customer and the adhesive used for installing the floor.

In the Human toxicity (cancer) the largest contribution is coming from the production stage where the thermal energy used in the manufacturing is contributing 53% to the total impact. Other minor contributions come from the Installation (Adhesive) and Use stage (Electricity). For the End of Life stage energy recovery from incineration and the respective energy substitution at the end of life results in a credit.

For Human toxicity (non-canc.) by far the biggest impact of 75% is coming from the installation stage, where the contribution of the adhesive is predominating this life cycle stage. A much smaller but significant contribution to the total impact is coming from the production stage where the main contributor is the raw material extraction and processing with a factor of 77%.

## References

| | |
|---|---|
| GABI 9 2012 | THINKSTEP AG; GaBi 9: Software-System and Database for Life Cycle Engineering. Copyright, TM. Stuttgart, Echterdingen, 1992-2017. |
| GABI 9 2012D | GaBi 9: Documentation of GaBi 9: Software-System and Database for Life Cycle Engineering. Copyright, TM. Stuttgart, Echterdingen, 1992-2017. http://documentation.gabi-software.com/ |
| UL ENVIRONMENT | UL Environment's Program Operator Rules |
| PE 2012<br><br>ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance | Description of Selected Impact Categories, Thinkstep AG, 2012<br><br>European Commission-Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook- Recommendations for Life Cycle Impact Assessment in the European context. First edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union; 2011 |
| **STANDARDS AND LAWS** | |
| DIN EN ISO 14044 | Environmental management - Life cycle assessment - Requirements and guidelines (ISO 14044:2006); English version EN ISO 14044 |
| ISO 14025 2006 | EN ISO 14025: Environmental labels and declarations — Type III environmental declarations — Principles and procedures |
| ISO 14040 2006 | Environmental management - Life cycle assessment - Principles and framework (ISO 14040); English version EN ISO 14040 |
| CEN/TR 15941 | Sustainability of construction works - Environmental product declarations - Methodology for selection and use of generic data; German version CEN/TR 15941 |
| EN 16810 | Resilient, textile and laminate floor coverings - Environmental product declarations - Product category rules |
| CPR | REGULATION (EU) No 305/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC |
| EN-ISO 10874 | Resilient, textile and laminate floor coverings – Classification |

# Life Cycle Assessment

## Marmoleum FR2

LCA study conducted by:
Forbo Flooring
Industrieweg 12
1566 JP Assendelft
The Netherlands

*March 2020*

Environment

**Marmoleum FR2**
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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## Nomenclature

| Abbreviation | Explanation |
|---|---|
| ADPF | Abiotic Depletion Potential Fossil |
| ADPE | Abiotic Depletion Potential Elements |
| AP | Acidification Potential |
| BLBSB | Benefits and Loads Beyond the System Boundary |
| CRU | Components for re-use |
| EE | Exported energy per energy carrier |
| EP | Eutrophication Potential |
| EPD | Environmental Product Declaration |
| FCSS | Floor covering standard symbol |
| FW | Use of net fresh water |
| GWP | Global Warming Potential |
| HWD | Hazardous waste disposed |
| LCA | Life Cycle Assessment |
| LCI | Life Cycle Inventory analysis |
| LCIA | Life Cycle Impact Assessment |
| MER | Materials for energy recovery |
| MFR | Materials for recycling |
| NRSF | Use of non-renewable secondary fuels |
| ODP | Ozone Layer Depletion Potential |
| PENRE | Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials |
| PENRM | Use of non-renewable primary energy resources used as raw materials |
| PENRT | Total use of non-renewable primary energy resources |
| PERE | Use of renewable primary energy excluding renewable primary energy resources used as raw materials |
| PERM | Use of renewable primary energy resources used as raw materials |
| PERT | Total use of renewable primary energy resources |
| PCR | Product Category Rules |
| POCP | Photochemical Ozone Creation Potential |
| RSF | Use of renewable secondary fuels |
| RSL | Reference Service Life |
| RWD | Radioactive waste disposed |
| SM | Use of secondary material |

## General

The present LCA study of the company Forbo Flooring, a manufacturer of resilient floor coverings, has been performed by Forbo Flooring and has been conducted according to the requirements of the European Standard EN16810 “Resilient, textile and laminate floor coverings – Environmental product declarations – Product category rules”. The LCA report was sent to verification on 21/02/2020

## Scope

This document is the LCA report for the “Environmental Product Declaration” (EPD) of "Marmoleum FR2".
The provision of an LCA report is required for each EPD of the EPD-program holder (UL Environment). This document shows how the calculation rules were applied and describes additional LCA information on the Life Cycle Assessment in accordance with the requirements of ISO 14040 series.

## Content, structure and accessibility of the LCA report

The LCA report provides a systematic and comprehensive summary of the project documentation supporting the verification of an EPD.
The report documents the information on which the Life Cycle Assessment is based, while also ensuring the additional information contained within the EPD complies with the requirements of ISO 14040 series.
The LCA report contains all of the data and information of importance for the details published in the EPD. Care has been given to all explanations as to how the data and information declared in the EPD arises from the Life Cycle Assessment.
The verification of the EPD is aligned towards the structure of the rule document based on ISO 14025, EN 15804 and EN16810.

## Goal of the study

The reason for performing this LCA study is to publish an EPD based on EN 16810, EN15804 and ISO 14025.
This study contains the calculation and interpretation of the LCA results for Marmoleum FR2.

Manufactured by
Forbo Flooring BV
Industrieweg 12
1566JP Assendelft
The Netherlands.
The following life cycle stages were considered:

- Product stage
- Transport stage
- Installation stage
- Use stage
- End-of-life stage
- Benefits and loads beyond the product system boundary

The main purpose of EPD is for use in business-to-business communication. As all EPD are publicly available on the website of UL Environment and therefore are accessible to the end consumer they can also be used in business-to-consumer communication.
The intended use of the EPD is to communicate environmentally related information and LCA results to support the assessment of the sustainable use of resources and of the impact of construction works on the environment

## Scope of the study

### *Declared / functional unit*

The declaration refers to the declared/functional unit of 1m² installed flooring product.

### *Declaration of construction products classes*

The LCA report refers to a manufacturer declaration of type 1a): Declaration of a specific product from a manufacturer's plant.
These products are also known under the following brand names:

- Marmoleum Concrete, Fresco, Real, Vivace, Walton Cirrus

They are produced at the following manufacturing site:
Forbo Flooring BV
Industrieweg 12
1566JP Assendelft
The Netherlands

FLOORING SYSTEMS

**Marmoleum FR2**
Resilient Linoleum Floor Covering

**According to ISO 14025 and EN 15804**

## Product Definition

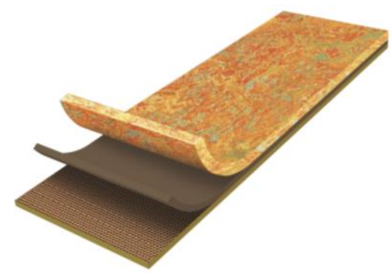
### Product Classification and description

Marmoleum is a resilient floor covering made from natural raw materials making it a preferable ecological and durable floor covering with a beautiful and colorful design. The key raw materials include linseed oil, which comes from the flax plant seeds, gum rosin from pine trees, recycled wood waste of wood from controlled forests, limestone and jute from the jute plant which is used for the backing. Because of the use of natural raw materials Marmoleum can be composted in an appropriate composting facility.

Linoleum is produced by Forbo Flooring for more than 150 years and our well-known brand Marmoleum is sold worldwide. This declaration refers to Marmoleum FR2 sheet 2.5 mm nominal thickness covering a broad range of designs and colors :

Concrete, Fresco, Real, Vivace, Walton Cirrus
Depending on color variations of these designs the recycled content can vary from 40 to 44%

Marmoleum FR2 is build up in 3 layers as illustrated in the figure 1.These three layers form one homogeneous product by the cross linking bondings formed during the oxidative curing process :

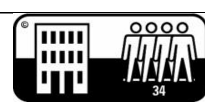


1. **Surface layer:** This layer gives Marmoleum its design and color. After finishing the product at the trimming department a factory finish is applied to protect the surface layer.
2. **Intermediate layer:** This layer is calendared on the jute backing and contains reused Linoleum.
3. **Backing:** The backing is woven jute.

The declaration refers to the declared/functional unit of 1m² installed flooring product.

### Range of application

Marmoleum FR2 is to be installed in the following use areas defined in EN–ISO 10874:

| Area of application | **Commercial** |
|---|---|
| **Marmoleum FR2 (2½ mm)** |  |

## Product Standard

The products considered in this EPD have the following technical specifications fire testing :

- Meets or exceeds Class 1 when tested in accordance with ASTM E 648/NFPA 253, Standard Test Method for

Critical Radiant Flux.

- Meets 450 or less when tested in accordance with ASTM E 662/NFPA 258, Standard Test Method for Smoke Density.
- Class HL3 when tested in accordance with EN 45545-2, Railway applications - Fire protection on railway vehicles - Part 2: Requirements for fire behavior of materials and components
- Class 1a when tested in accordance with BS6853, fire test to railway components, code of practice for fire precautions in the design and construction of passenger carrying trains

## Accreditation

- ISO 9001 Quality Management System\
- ISO 14001 Environmental Management System
- ISO 45001 Occupational Health and Safety Management Systems
- SA 8000 Social Accountability standard

## Delivery status

| Characteristics | Nominal Value | Unit |
|---|---|---|
| Product thickness | 2.5 | mm |
| Product Weight 2.5 mm | 3000 | g/m$^2$ |
| Rolls Width<br>Length | 2.00<br>< 32 | meter |

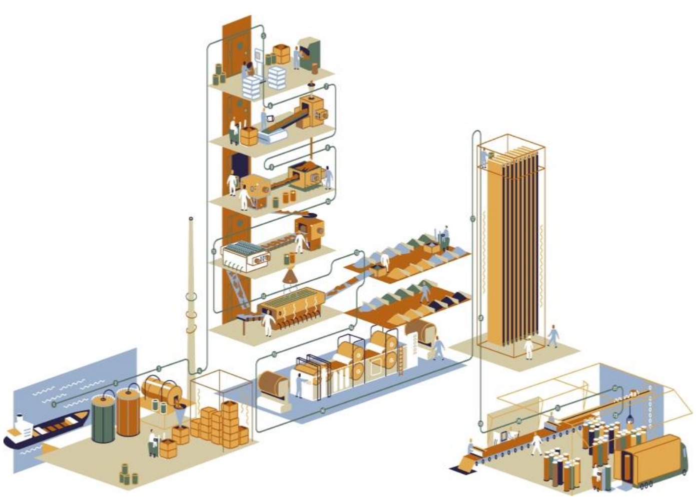
## Material Content

| Component | Material | Availability | Amount [%] | Origin |
|---|---|---|---|---|
| **Binder** | Linseed oil<br>Gum rosin<br>Tall oil | Bio based crop<br>Bio based crop<br>Bio based waste product from paper Industry | 18<br>2<br>9 | USA/Canada/Europe<br>Indonesia/China<br>USA |
| **Filler** | Wood flour<br><br>Alumina trihydrate<br>Reused Marmoleum<br>Calcium Carbonate | Bio based waste product from wood processing<br>Limited mineral<br><br>Abundant mineral | 22<br><br>25<br>9<br>3 | Germany<br><br>Germany<br>Internal<br>Germany |
| **Pigment** | Titanium dioxide<br>Various other pigments | Limited mineral<br>Limited mineral | 2<br>0.5 | Global<br>Global |
| **Backing** | Jute | Bio based crop | 9 | India/Bangladesh |
| **Finish** | Lacquer | Fossil limited | 0.5 | Netherlands |

## roduction of Main Materials

- **Linseed oil** : Linseed oil is obtained by pressing the seeds of the flax plant. After filtering a clear golden yellow liquid remains.
- **Gum rosin** : Rosin is obtained by wounding pine trees. The crude gum is collected and is separated into turpentine and rosin by distillation.
- **Tall oil** : Tall oil is a post industrial waste product coming from the paper industry and is consisting of vegetable oil and rosin.
- **Wood flour** : Postindustrial bio based soft wood waste from the wood industry, which is milled into flour.
- **Alumina trihydrate:** Fire retardant filler obtained by extracting aluminium hydroxide from Bauxite which is naturally occurring in the Earth's surface. Imparts fire retardance of Marmoleum FR2
- **Calcium carbonate** : An abundant mineral found in all parts of the world as the chief substance in rocks (i.e., marble and limestone). It can be ground to varying particle sizes and is widely used as filler.
- **Titanium dioxide** : A white pigment produced from the mineral rutile, a naturally occurring form of titanium dioxide. The production of the pigment is a large-scale chemical process
- **Various other pigments** : The vast majority of the used colour pigments are iron oxide based.
- **Jute** : Jute fibre is extracted from the stem of the jute plant by floating it in water. For yarn production fibre bands are obtained by carding, stretching, spinning, warping and sizing. Finally the yarn is woven.
- **Lacquer** : The factory applied lacquer – Topshield 2 – is a waterborne UV cured double layer factory coating – acrylate hybrid dispersion.

### Production of the Floor Covering



Marmoleum is produced in several stages starting with the oxidation of linseed oil mixed with tall oil and rosin. With the influence of oxygen from the atmosphere a tough sticky material is obtained called linoleum cement. The linoleum cement is stored in containers for a few days for further reaction and after this it is mixed with wood flour, calcium carbonate, reused waste (if applicable), titanium dioxide and pigments. This mixture is calendared on a jute substrate and stored in drying rooms, to cure till the required hardness is reached. After approximately 14 days the material is taken out from the drying room to the trimming department where the factory finish is applied on the surface of the product and the end inspection is done. Finally the edges are trimmed and the sheet is cut to length into rolls of approximately 32 meter. The trimmings and the rejected product are reused.

### Health, Safety and Environmental Aspects during Production

- ISO 14001 Environmental Management System
- OHSAS 18001 Occupational Health and Safety Management Systems
- SA 8000 Social Accountability standard

### Production Waste

Rejected material and the cuttings of the trimming stage are being reused in the manufacturing process. Packaging materials are being collected separately and externally recycled.

## Delivery and Installation of the Floor Covering

### Delivery

A worldwide distribution by truck and container ship is considered. On average every square meter of Marmoleum is transported as follows:

| | |
|---|---|
| Transport distance 40 t truck | 634 km |
| Transport distance 7.5t truck (Fine distribution) | 162 km |
| Capacity utilization trucks (including empty runs) | 85 % |
| Transport distance Ocean ship | 2290 km |
| Capacity utilization Ocean ship | 48% |

## Installation

Because of the specific techniques used during the installation of Marmoleum 6% of the material is cut off as installation waste. For installation of Marmoleum on the floor an average scenario has been modeled (assuming 0.280 kg/m$^2$ of adhesive is required).
Waste during the installation process may be recycled as floor covering through the manufacturers' facilities or thermally recycled in a waste incineration plant. Since the major part of Marmoleum is sold in Europe the European electricity grid mix is used in the calculations for the energy recovery during incineration.

### Health, Safety and Environmental Aspects during Installation

Forbo flooring recommends to use a low emission EC1 adhesive for installing Marmoleum.

### Waste

Waste during the installation process may be recycled as floor covering through the manufacturers' facilities or thermally recycled in a waste incineration plant. Since the major part of Marmoleum is sold in Europe the European electricity grid mix is used in the calculations for the energy recovery during incineration.

### Packaging

Cardboard tubes and packaging paper can be collected separately and should be used in a local recycling process. In the calculation model 100% incineration is taken into account for which there is a credit received.

## Use stage

The service lifetime of a floor covering for a certain application on a floor is too widespread to give one common number. For this EPD model the reference service lifetime (RSL) is set to one year. This means that all impacts for the use phase are based on the cleaning and maintenance model for one year. Depending on the area of use, the technical lifetime advised by the manufacturer and the estimated time on the floor by the customer, the service lifetime can be determined. The use phase impacts should be calculated with the foreseen service life to arrive at the total environmental impact.

## Cleaning and Maintenance

| Level of use | Cleaning Process | Cleaning Frequency | Consumption of energy and resources |
|---|---|---|---|
| Commercial/Residential/Industrial | Vacuuming | Twice a week | Electricity |
| | Damp mopping | Once a week | Hot water<br>Neutral detergent |

For the calculations the following cleaning regime is considered:

- Dry cleaning with a 1.5 kW vacuum cleaner for 0.21 min/m$^2$, twice a week. This equates to 0.55 kWh/m$^2$*year.
- Once a week wet cleaning with 0.062 l/m$^2$ water and 0.0008 kg/m$^2$ detergent. This result in the use of 3.224 l/m$^2$*year water and 0.04 kg/m$^2$*year detergent. The wet cleaning takes place without power machine usage. Waste water treatment of the arising waste water from cleaning is considered.

The cleaning regime that is recommended in practice will be highly dependent on the use of the premises where the floor covering is installed. In high traffic areas more frequent cleaning will be needed compared to areas where there is low traffic. The use of an entrance mat of at least four steps will reduce the cleaning frequency.
The cleaning regime used in the calculations is suitable for high traffic areas.

### Prevention of Structural Damage

All newly laid floors should be covered and protected from with a suitable non-staining protective covering if other building activities are still in progress.
Use protective feet on chairs and tables to reduce scratching. Castor wheels should be suitable for resilient floor coverings

### Health Aspects during Usage

Low VOC cleaning materials are available for use in maintaining Marmoleum FR2.

## End of Life

The deconstruction of installed Marmoleum from the floor is done mechanically and the electrical energy needed for this is estimated to be 0.03 kWh/sqm. This amount of energy is taken into account for the calculations.
For the end of life stage no landfilling is taken into account, since the vast majority of the countries in which Marmoleum is sold are having a non landfill policy. Because of the high calorific value of Marmoleum the incineration is very profitable as a waste to energy conversion.

## Life Cycle Assessment

A full Life Cycle Assessment has been carried out according to ISO 14040 and ISO 14044.

The following Life Cycle Stages are assessed :

- A1-3 : Product Stage (Raw material acquisition, transportation to Manufacturing and Manufacturing)
- A4-5 : Construction process stage (Transport Gate to User, installation flooring)
- B2 : Use Stage (Maintenance of the floor)
- C1-4 : End of Life Stage (Deconstruction, transport, waste processing, Disposal)
- D : Benefits and loads beyond the system boundary (Reuse, recovery, recycling potential)

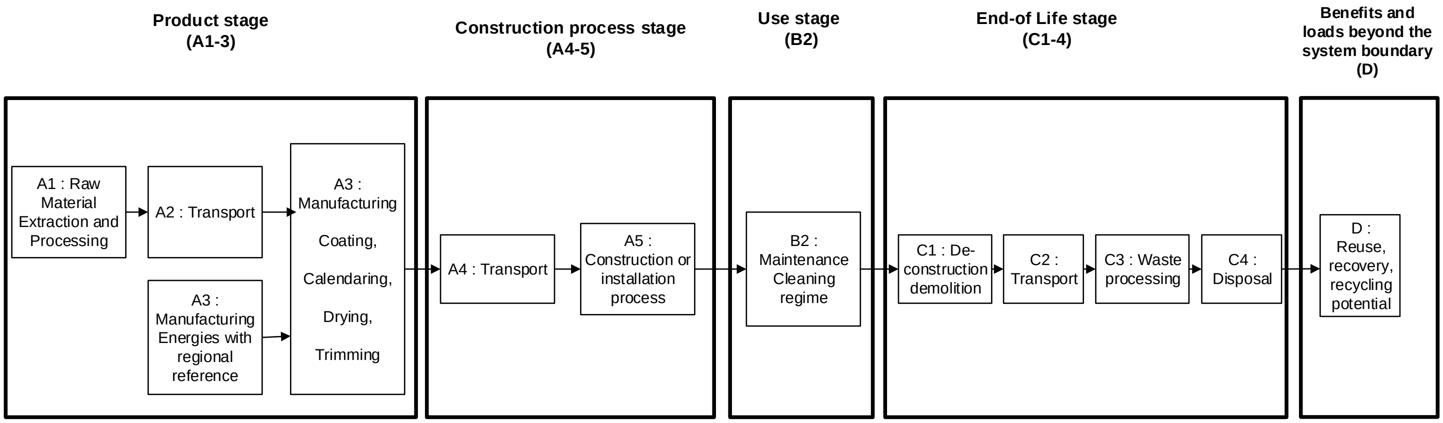



**Figure 3 : Flow chart of the Life Cycle Assessment**

Comparisons of different floor coverings are only allowed, where EN 15804 consistent and/or preverified background data and EN 15804 consistent calculation methods and database versions are used and when the building context is taken into account, i.e. on the basis of the same use-classification (EN ISO 10874), same service life and comparable assumptions for the end of life.

## Description of the declared Functional Unit

The functional unit is one square meter of installed product and the use stage is considered for one year of service life.

## Cut off Criteria

The cut-off criteria shall be 1% of renewable and non-renewable primary energy usage and 1% of the total mass of the unit process. The total neglected input flows per module shall be a maximum of 5% of energy usage and mass.

In practice, in this assessment, all data from the production data acquisition are considered, i.e. all raw materials used as per formulation, use of water, electricity and other fuels, the required packaging materials, and all direct production waste. Transport data on all considered inputs and output material are also considered.

## LCA Data

As a general rule, specific data derived from specific production processes or average data derived from specific production processes have been used as the first choice as a basis for calculating an EPD.

For life cycle modeling of the considered products, the GaBi 9 Software System for Life Cycle Engineering, developed by THINKSTEP AG, has been used. All relevant LCA datasets are taken from the GaBi 9 software database. The datasets from the database GaBi are documented in the online documentation. To ensure comparability of results in the LCA, the basic data of GaBi database were used for energy, transportation and auxiliary materials.

## Data Quality

The requirements for data quality and LCA data correspond to the specifications of the PCR.

Foreground data are based on 1 year averaged data (year 2019). The reference ages of LCA datasets vary but are given in the table in the Appendix. The time period over which inputs to and outputs from the system is accounted for is 100 years from the year for which the data set is deemed representative. The technological LCA of the collected data reflects the physical reality of the declared product. The datasets are complete, conform to the system boundaries and the criteria for the exclusion of inputs and outputs and are geographical representative for the supply chain of Forbo flooring.

For life cycle modeling of the considered products the GaBi 9 Software System for Life Cycle Engineering, developed by THINKSTEP AG, is used. All relevant LCA datasets are taken from the GaBi 9 software database. The last revision of the used data sets took place within the last 10 years.

*Table 3: LCA datasets used in the LCA model*

| Data set | Region | Reference year |
|---|---|---|
| Linseed oil | Germany | 2012 |
| Limestone flour | Germany | 2019 |
| Tall oil | Europe | 2012 |
| Iron oxide | Germany | 2012 |
| Pigment | Germany | 2007 |
| Titanium dioxide | Europe | 2012 |
| Wood flour | Europe | 2017 |
| Alumina trihydrate | Europe | 2019 |
| Calcium carbonate | Europe | 2019 |
| Colophony | France | 2012 |
| Jute | India | 2012 |
| Urethane / acrylic hybrid dispersion | Europe | 2019 |
| Water (desalinated; deionized) | Germany | 2019 |
| Detergent (ammonia based) | Germany | 2007 |
| Adhesive for resilient flooring | Germany | 2012 |
| Waste incineration of particle board | Europe | 2019 |
| Paper/cardboard incineration | Europe | 2019 |
| Electricity from Hydro power | Norway | 2019 |
| Power grid mix | Europe | 2019 |
| Thermal energy from natural gas | Netherlands | 2019 |
| Thermal energy from natural gas | Europe | 2019 |
| Trucks | Global | 2019 |
| Municipal waste water treatment (50% agricultural sludge application, 50% sludge incineration). | Germany | 2019 |

| Data set | Region | Reference year |
|---|---|---|
| Municipal waste water treatment (Sludge incineration). | Germany | 2019 |
| Waste incineration of paper/cardboard | Europe | 2019 |
| Container ship | Global | 2019 |
| Diesel mix at refinery | Europe | 2019 |
| Heavy fuel oil at refinery (1.0wt.% S) | Europe | 2019 |
| Corrugated board | Europe | 2019 |
| Kraft liner (paper) | Europe | 2019 |
| Tap water | Europe | 2019 |

The documentation of the LCA data sets can be taken from the GaBi documentation.

## System Boundaries

Production Stage includes provision of all materials, products and energy, packaging processing and its transport, as well as waste processing up to the end-of waste state or disposal of final residues during the product stage.

Transport and Installation Stage includes provision of all materials, products and energy, as well as waste processing up to the end-of-waste state or disposal of final residues during the construction stage. These information modules also include all impacts and aspects related to any losses during this construction stage (i.e. production, transport, and waste processing and disposal of the lost products and materials). For the transportation a worldwide distribution is considered.

Use Stage includes provision and transport of all materials, products and related energy and water use, as well as waste processing up to the end-of-waste state or disposal of final residues during this part of the use stage. These information modules also include all impacts and aspects related to the losses during this part of the use stage (i.e. production, transport, and waste processing and disposal of the lost products and materials).

End of Life Stage includes provision and all transports, provision of all materials, products and related energy and water use. It also includes any declared benefits and loads from net flows leaving the product system that have not been allocated as co-products and that have passed the end-of-waste state in the form of reuse, recovery and/or recycling potentials.

## Power mix

The selection of LCA data for the electricity generation is in line with the PCR.

The products are manufactured in Assendelft, the Netherlands. The GaBi 9 Hydropower dataset has therefore been used (reference year 2019). The energy supplier is providing Forbo with a certificate every year.

## $CO_2$-Certificates

No $CO_2$-certificates are considered in this study.

## Allocations

In the present study some allocations have been made. Detailed explanations can be found in the chapters below.

### Co-product allocation

No co-product allocation occurs in the product system.

### Allocation of multi-Input processes

The Production and End of Life stage include incineration plants. In these processes different products are treated together within a process. The allocation procedures followed in these cases are based on a physical classification of the mass flows or calorific values.

Credits from energy substitution are allocated to the production stage, because the gained energy from energy substitution is lower than the energy input in this stage. The same quality of energy is considered.

### Allocation procedure of reuse, recycling and recovery

The installation waste and end of life waste is fed into incineration processes. Incineration processes include cogeneration processes which give thermal and power energy as outputs. It is assumed that this recovered energy offsets that produced by the European average grid mix and thermal energy generation from natural gas.

### Description of the allocation processes in the LCA report

The description of allocation rules in of this LCA report meets the requirements of the PCR.

## Description of the unit processes in the LCA report

The modeling of the unit processes reported for the LCA are documented in a transparent way, respecting the confidentiality of the data present in the LCA report.

In the following tables the type and amount of the different input and output flows are listed for 1m² produced flooring; installed flooring includes the material loss during installation (6%):

*Table 4: Composition of linoleum surface layer*

| Process data | Unit | Marmoleum FR2 |
|---|---|---|
| Alumina trihydrate | kg/m2 | 0.73 |
| Linseed oil | kg/m2 | 0.51 |
| Iron oxide ($Fe_2O_3$) | kg/m2 | 0.02 |
| Pigment | kg/m2 | 0.003 |
| Colophony (rosin) | kg/m2 | 0.06 |
| Tall oil (Bio based waste product from paper Industry) | kg/m2 | 0.26 |
| Titanium dioxide | kg/m2 | 0.06 |
| Calcium Carbonate | kg/m2 | 0.10 |
| Wood flour (Bio based waste product from wood processing) | kg/m2 | 0.64 |
| Reused Marmoleum | kg/m2 | 0.27 |

*Table 6: Composition of linoleum substrate layer*

| Process data | Unit | Marmoleum FR2 |
|---|---|---|
| Jute | kg/m2 | 0.240 |

*Table 7: Composition of lacquer*

| Process data | Unit | Marmoleum FR2 |
|---|---|---|
| Urethane / acrylic hybrid dispersion | kg/m2 | 0.0140 |
| Water (desalinated; demonized) | kg/m2 | 0.0210 |

*Table 8: Production related inputs/outputs*

| Process data | Unit | Marmoleum FR2 |
|---|---|---|
| **INPUTS** | | |
| Linoleum surface layer | kg | 1.84 |
| Linoleum intermediate layer | kg | 0.88 |
| Linoleum substrate layer | kg | 0.24 |
| Lacquer | kg | 0.04 |
| Electricity | MJ | 8.28 |
| Thermal energy from natural gas | MJ | 15.88 |
| **OUTPUTS** | | |
| Marmoleum | kg | 2.90 |
| Waste | kg | 0.10 |

*Table 9: Packaging requirements (per m² manufactured product)*

| Process data | Unit | Marmoleum FR2 |
|---|---|---|
| Corrugated board | kg | 0.05 |
| Kraftliner (paper) | kg | 0.02 |

*Table 10: Transport distances*

| Process data | Unit | Road | Truck size | Ship |
|---|---|---|---|---|
| Limestone flour | km | 498 | 14 - 20t gross weight / 11,4t payload capacity | - |
| Linseed oil | km | 212 | | 2740 |
| Iron oxide ($Fe_2O_3$) | km | 263 | | - |
| Pigment | km | 379 | | - |
| Colophony (rosin) | km | 246 | | 15800 |
| Tall oil | km | 100 | | 7060 |
| Titanium dioxide | km | 112 | | - |
| Wood flour | km | 355 | | - |
| Jute | km | 155 | | 14800 |
| Lacquer | km | 2 | | - |
| Corrugated board boxes | km | 115 | | - |
| Kraftliner (paper) | km | 942 | | - |
| Transport to construction site :<br>-Transport distance 40 t truck<br>-Transport distance 7.5t truck (Fine distribution) | km | 796<br>634<br>162 | 34 - 40 t gross weight / 27t payload capacity<br>7,5 t - 12t gross weight / 5t payload capacity | 2290 |
| Waste transport to incineration | km | 100 | 7,5 t - 12t gross weight / 5t payload capacity | - |

*Table 11: Inputs/outputs from Installation*

| Process data | Unit | Marmoleum FR2 |
|---|---|---|
| **INPUTS** | | |
| Marmoleum | kg | 3.07 |
| Adhesive (30% water content)<br>- Water<br>- Acrylate co-polymer<br>- Styrene Butadiene co-polymer<br>- Limestone flour<br>- Sand | kg | 0.28 |
| **OUTPUTS** | | |
| Installed Marmoleum | kg | 2.90 |
| Installation Waste (Marmoleum and packaging) | kg | 0.17 |

*Table 12: Inputs from use stage (per $m^2$.year of installed product)*

| Process data | Unit | Marmoleum FR2 |
|---|---|---|
| Detergent | kg/year | 0.04 |
| Electricity | kWh/year | 0.55 |
| Water | kg/year | 3.224 |

*Table 13: Disposal*

| Process data | Unit | Marmoleum FR2 |
|---|---|---|
| Post-consumer Marmoleum to incineration | % | 100 |

## Life Cycle Inventory Analysis

In table 14 the environmental impacts for one lifecycle are presented for Marmoleum FR2. In the table 15 the environmental impacts are presented for all the lifecycle stages.

**Table 14: Results of the LCA – Environmental impacts one lifecycle (one year) – Marmoleum FR2**

| Impact Category : CML 2001 – Jan. 2016 | Marmoleum FR2 | Unit |
|---|---|---|
| Global Warming Potential (GWP 100 years) | 5,88E+00 | kg CO2-Equiv. |
| Ozone Layer Depletion Potential (ODP. steady state) | 2,16E-08 | kg R11-Equiv. |
| Acidification Potential (AP) | 4,54E-02 | kg SO2-Equiv. |
| Eutrophication Potential (EP) | 1,11E-02 | kg Phosphate-Equiv. |
| Photochem. Ozone Creation Potential (POCP) | 1,72E-03 | kg Ethene-Equiv. |
| Abiotic Depletion Potential Elements (ADPE) | 3,00E-06 | kg Sb-Equiv. |
| Abiotic Depletion Potential Fossil (ADPF) | 6,68E+01 | [MJ] |

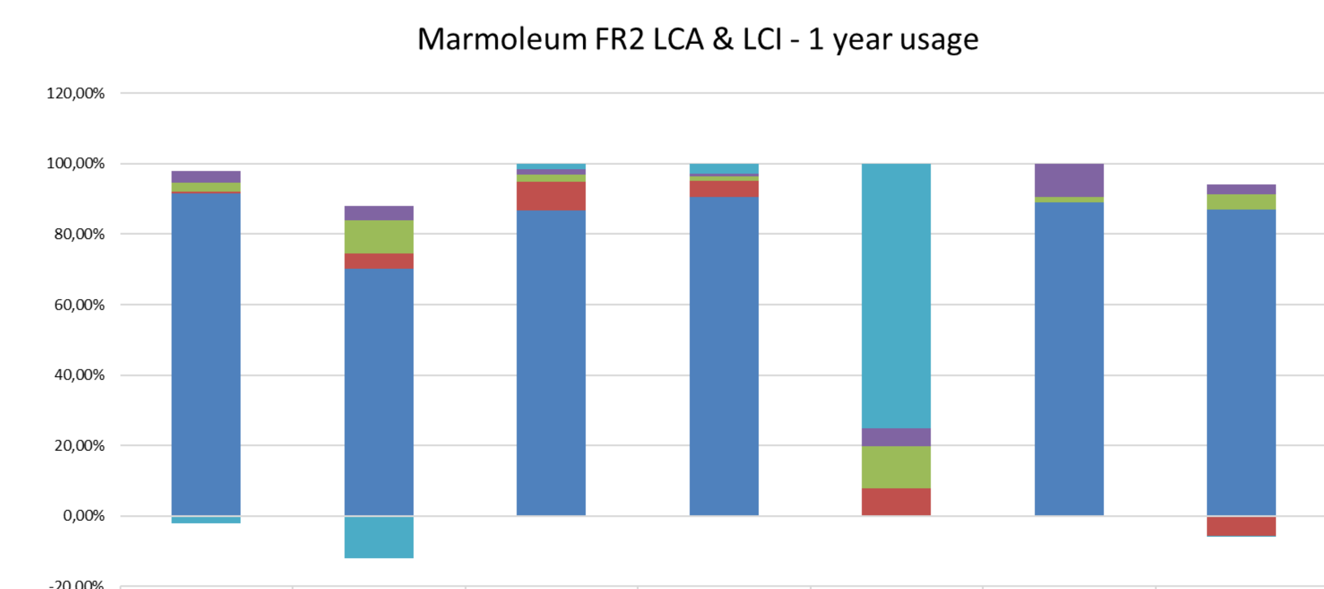
*Table 15: Results of the LCA – Environmental impact for Marmoleum FR2 (one year)*

| Impact Category : CML 2001 – Jan. 2016 | | Manufacturing | Installation | | Use (1yr) | End of Life | | | Credits |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **A1-3** | **A4** | **A5** | **B2** | **C1** | **C2** | **C3** | **D** |
| GWP | [kg $CO_2$-Eq.] | -7,49E-03 | 4,56E-01 | 7,16E-01 | 2,91E-01 | 2,23E-01 | 2,03E-02 | 5,21E+00 | -1,03E+00 |
| ODP | [kg CFC11-Eq.] | 1,92E-08 | 4,27E-17 | 3,33E-10 | 2,06E-09 | 6,26E-15 | 3,35E-18 | 9,51E-16 | -1,43E-14 |
| AP | [kg $SO_2$-Eq.] | 3,94E-02 | 3,70E-03 | 8,82E-04 | 7,48E-04 | 6,34E-04 | 4,93E-05 | 1,72E-03 | -1,75E-03 |
| EP | [kg $PO_4^{3-}$- Eq.] | 1,01E-02 | 4,99E-04 | 1,40E-04 | 9,43E-05 | 5,94E-05 | 1,23E-05 | 4,28E-04 | -1,89E-04 |
| POCP | [kg Ethen Eq.] | 1,70E-03 | -1,11E-04 | 8,22E-05 | 5,40E-05 | 4,03E-05 | -1,68E-05 | 1,10E-04 | -1,38E-04 |
| ADPE | [kg Sb Eq.] | 2,86E-06 | 1,68E-08 | 7,89E-08 | 1,03E-07 | 7,11E-08 | 1,56E-09 | 5,12E-08 | -1,87E-07 |
| ADPF | [MJ] | 6,19E+01 | 3,73E+00 | 8,27E+00 | 3,53E+00 | 2,40E+00 | 2,75E-01 | 1,31E+00 | -1,46E+01 |

GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophication potential; POCP = Formation potential of tropospheric ozone photochemical oxidants; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources

The relative contribution of each process stage to each impact category for Marmoleum Striato FR is shown in figure 4.

*Figure 4: relative contribution of each process stage to each impact category for Marmoleum FR2 for a one year usage.*




| | Abiotic Depletion (Elements) | Abiotic Depletion (Fossil) | Acidification Potential | Eutrophication Potential | Global Warming Potential | Ozone Layer Depletion Potential | Photochem. Ozone Creation Potential |
|---|---|---|---|---|---|---|---|
| End of Life | -2,02% | -12,06% | 1,44% | 2,79% | 75,05% | 0,00% | -0,23% |
| Use | 3,30% | 4,01% | 1,65% | 0,85% | 4,94% | 9,54% | 2,77% |
| Installation | 2,53% | 9,39% | 1,94% | 1,26% | 12,15% | 1,54% | 4,21% |
| Transport | 0,54% | 4,24% | 8,15% | 4,48% | 7,74% | 0,00% | -5,69% |
| Production | 91,61% | 70,30% | 86,82% | 90,63% | -0,13% | 88,92% | 87,10% |

## Interpretation

The interpretation of the results has been carried out considering the assumptions and limitations declared in the EPD, both methodology- and data-related for a one year usage.

**T**he LCA for GWP reflects the use of renewable raw materials for the production of Marmoleum (linseed oil and jute). Carbon dioxide, a greenhouse gas, is locked in from the atmosphere in the course of the plant growth via photosynthesis and stored during the use stage. This carbon dioxide is not released until the end of life when it is incinerated with energy recovery – this process accounts for the greatest emission of greenhouse gases in the life cycle of the product.

For the production stage of Marmoleum FR2 the uptake of CO2 is higher than the emission of greenhouse gasses resulting in a slightly negative life cycle stage.

In the other 6 impact categories (ODP, AP, EP, POCP, ADPE, ADPF) the production stage has the main contribution to the overall impact. For these categories the main contributor in the production stage is the raw material extraction and processing with a share of 60-100% of total impacts from the production stage.

Forbo declares in the EPD a worldwide distribution by truck (796 km) and container ship (2290 km). For this scenario the transport has a relevance of 4-11% in the impact categories GWP, AP, EP and ADPF.

The negative impact for POCP for the transportation stage is remarkable, but it is assumed that NO and CO reduces the accumulated ozone to NO2, CO2 and O2. This means, that high concentrations of ozone do not often occur near hydrocarbon emission sources. Higher ozone concentrations more commonly arise in areas of clean air, such as forests, where there is less NO and CO.

For GWP and ADPF the adhesive for the flooring installation has a significant impact. The LCA for the installation is based on an assumption of 280 g/m² adhesive.

The use stage is calculated for one year of service life time with a conservative scenario based on a cleaning regime suitable for high traffic areas. The electricity and detergent used to clean the floor are the main contributors for this life cycle stage.

Energy recovery from incineration and the respective energy substitution at the end of life results in a credit as reported in the End of Life stage.

## Parameters describing resource use

In the table 16 the parameters describing resource use are presented for all the lifecycle stages.

*Table 16: Results of the LCA – Resource use for Marmoleum FR2 (one year)*

| | | Manufacturing | Installation | | **Use (1yr)** | End of Life | | | Credits |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **A1-3** | **A4** | **A5** | **B2** | **C1** | **C2** | **C3** | **D** |
| PERE | [MJ] | 3,15E+01 | - | - | - | - | - | - | - |
| PERM | [MJ] | 3,95E+01 | - | - | - | - | - | - | - |
| PERT | [MJ] | 7,10E+01 | 1,52E-01 | 3,31E-01 | 1,68E+00 | 1,63E+00 | 1,60E-02 | 2,20E-01 | -3,72E+00 |
| PENRE | [MJ] | 4,89E+01 | - | - | - | - | - | - | - |
| PENRM | [MJ] | 1,63E+01 | - | - | - | - | - | - | - |
| PENRT | [MJ] | 6,52E+01 | 3,75E+00 | 8,45E+00 | 5,34E+00 | 4,04E+00 | 2,76E-01 | 1,51E+00 | -1,83E+01 |
| SM | [kg] | -5,99E-02 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| RSF | [MJ] | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| NRSF | [MJ] | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 0,00E+00 |
| FW | [$m^3$] | 6,24E-02 | 2,57E-04 | 2,12E-03 | 2,02E-03 | 1,92E-03 | 2,70E-05 | 1,19E-02 | -4,39E-03 |

PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water

## Other environmental information describing different waste categories and output flows

In the tables 17 other environmental information describing different waste categories and output flows are presented for all the lifecycle stages.

*Table 17: Results of the LCA – Output flows and Waste categories for Marmoleum FR2 (one year)*

| | | Manufacturing | Transport | Installation | **Use (1yr)** | End of Life/credits | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **A1-3** | **A4** | **A5** | **B2** | **C1** | **C2** | **C3** | **D** |
| HWD | [kg] | 4,11E-08 | 1,43E-07 | 3,41E-09 | 2,04E-09 | 1,93E-09 | 1,54E-08 | 1,08E-09 | -7,54E-09 |
| NHWD | [kg] | 3,18E-01 | 2,15E-04 | 5,77E-03 | 6,21E-03 | 2,94E-03 | 2,24E-05 | 3,66E-02 | -7,93E-03 |
| RWD | [kg] | 1,30E-03 | 4,89E-06 | 7,22E-05 | 6,93E-04 | 6,51E-04 | 3,74E-07 | 7,61E-05 | -1,49E-03 |
| CRU | [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 |
| MFR | [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 |
| MER | [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 |
| EE Power | [MJ] | 0,00E+00 | 0,00E+00 | 4,38E-01 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 5,93E+00 | 0,00E+00 |
| EE Thermal energy | [MJ] | 0,00E+00 | 0,00E+00 | 7,79E-01 | 0,00E+00 | 0,00E+00 | 0,00E+00 | 1,05E+01 | 0,00E+00 |

HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; RWD = Radioactive waste disposed; CRU = Components for re-use; MFR = Materials for recycling; MER = Materials for energy recovery; EE = Exported energy per energy carrier

## Additional Environmental Information

To be fully transparant Forbo Flooring does not only want to declare the environmental impacts required in the PCR, but also the impacts on human health and eco-toxicity.

### Toxicity

For this calculations the USEtoxTM model is used as being the globally recommended preferred model for characterization modelling of human and eco-toxic impacts in LCIA by the United Nations Environment Programme SETAC Life Cycle Initiative.

According to the "ILCD Handbook: Recommendations for Life Cycle Impact Assessment in the European context" the recommended characterization models and associated characterization factors are classified according to their quality into three levels:

- Level I (recommended and satisfactory),
- level II (recommended but in need of some improvements)
- level III (recommended, but to be applied with caution).

A mixed classification sometimes is related to the application of the classified method to different types of substances. USEtoxTM is classified as Level II / III, unlike for example the CML impact categories which are classified as Level I.

*Table 18: Results of the LCA – Environmental impacts one lifecycle (one year) – Marmoleum FR2*

| Impact Category : USEtox | Marmoleum FR2 | Unit |
|---|---|---|
| Eco toxicity | 4,05E-03 | PAF m3.day |
| Human toxicity, cancer | 5,14E-10 | Cases |
| Human toxicity, non-canc. | 8,36E-11 | Cases |

In the following table the impacts are subdivided into the lifecycle stages.

*Table 19: Results of the LCA – Environmental impact for Marmoleum FR2 (one year)*

| Impact Category : USEtox | Unit | Production | Transport | Installation | Use (1yr) | End of Life |
|---|---|---|---|---|---|---|
| Eco toxicity | PAF m3.day | 2,23E-03 | 8,49E-04 | 8,44E-04 | 4,21E-04 | -2,97E-04 |
| Human toxicity, cancer | cases | 5,37E-10 | 9,53E-13 | 1,77E-11 | 3,01E-11 | -7,12E-11 |
| Human toxicity, non-canc. | cases | 2,91E-11 | 3,54E-13 | 5,45E-11 | 7,26E-13 | -1,02E-12 |

### *Interpretation*

The interpretation of the results has been carried out considering the assumptions and limitations declared in the EPD, both methodology- and data-related for a one year usage.

The Eco-toxicity is mostly dominated by the production stage in which the raw materials are having the biggest impact with a share of around 41%. The other main contributors in the production stage are the thermal energy and the packaging of the end product during manufacturing. Other main contributor of the total life cycle are the transport to the customer and the adhesive used for installing the floor.

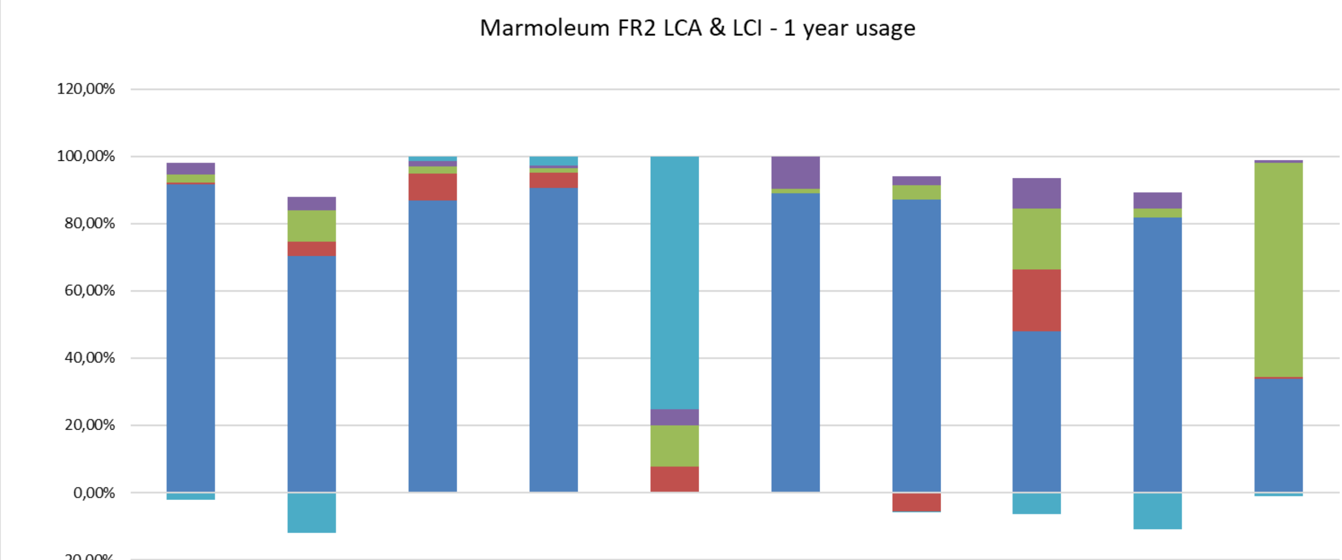
In the Human toxicity (cancer) the largest contribution is coming from the production stage where the thermal energy used in the manufacturing is contributing 53% to the total impact. Other minor contributions come from the Installation (Adhesive) and Use stage (Electricity). For the End of Life stage energy recovery from incineration and the respective energy substitution at the end of life results in a credit.

For Human toxicity (non-canc.) by far the biggest impact of 75% is coming from the installation stage, where the contribution of the adhesive is predominating this life cycle stage. A much smaller but significant contribution to the total impact is coming from the production stage where the main contributor is the raw material extraction and processing with a factor of 77%.

## Interpretation main modules and flows

The interpretation of the main modules and flows contributing to the total impact in each impact category is presented in following figures and tables.

*Figure 5: relative contribution of each process stage to each impact category for Marmoleum FR2 for a one year usage.*




| | Abiotic Depletion (Elements) | Abiotic Depletion (Fossil) | Acidification Potential | Eutrophication Potential | Global Warming Potential | Ozone Layer Depletion Potential | Photochem. Ozone Creation Potential | Ecotoxicity | Human toxicity, cancer | Human toxicity, non-canc. |
|---|---|---|---|---|---|---|---|---|---|---|
| End of Life | -2,02% | -12,06% | 1,44% | 2,79% | 75,05% | 0,00% | -0,23% | -6,40% | -10,84% | -1,19% |
| Use | 3,30% | 4,01% | 1,65% | 0,85% | 4,94% | 9,54% | 2,77% | 9,06% | 4,58% | 0,85% |
| Installation | 2,53% | 9,39% | 1,94% | 1,26% | 12,15% | 1,54% | 4,21% | 18,17% | 2,69% | 63,62% |
| Transport | 0,54% | 4,24% | 8,15% | 4,48% | 7,74% | 0,00% | -5,69% | 18,28% | 0,15% | 0,41% |
| Production | 91,61% | 70,30% | 86,82% | 90,63% | -0,13% | 88,92% | 87,10% | 48,09% | 81,74% | 33,93% |

*Table 20: Main modules and flows contributing to the total impact in each impact category for Marmoleum FR2 for a one year usage*

| Impact Category | Stage | Module | | Main contributor | Main contributing flows |
|---|---|---|---|---|---|
| GWP | Production | Raw Material Extraction | -1.26 kg $CO_2$-equiv. | Linseed oil (-1.9 kg $CO_2$ eq.) Titanium dioxide (0.34 kg $CO_2$eq.) | Production : Renewable resources, Carbon dioxide<br>Production : Inorganic emissions to air, Carbon dioxide |
| | | Transport of Raw materials | 0.16 kg $CO_2$-equiv. | Means of transport (truck, container ship) and their fuels | |
| | | Manufacturing | 1.08 kg $CO_2$-equiv. | 97% Thermal energy | |
| | Transport | Transport Gate to User | | Means of transport (truck, container ship) and their fuels | Transport & Installation : Inorganic emissions to air, Carbon dioxide |
| | Installation | Installation | | 48% Adhesive<br>52% Incineration of waste | |
| | Use | Use | | 78% Electricity | Use : Inorganic emissions to air, Carbon |

| Impact Category | Stage | Module | | Main contributor | Main contributing flows |
|---|---|---|---|---|---|
| | | | | 20% Detergent | dioxide |
| | EOL | EOL | | Incineration of post-consumer linoleum flooring<br>Energy substitution from incineration | EOL : Inorganic emissions to air, Carbon dioxide |
| ODP | Production | Raw Material Extraction | 100% | 41% Tall oil<br>19% Titanium dioxide<br>16% Colophony<br>18% Linseed oil | Production : Halogenated organic emissions to air, R114 (Dichlorotetrafluorethane) |
| | | Transport of Raw materials | < 0.01% | Means of transport (truck, container ship) and their fuels | |
| | | Manufacturing | < 0.01% | 100% Paper and card packaging | |
| | Transport | Transport Gate to User | | Means of transport (truck, container ship) and their fuels | Transport & Installation : Halogenated organic emissions to air, R114 (Dichlorotetrafluorethane) |
| | Installation | Installation | | 100% Adhesive | |
| | Use | Use | | 100% Detergent | Use : Halogenated organic emissions to air, R11 (Trichlorofluoromethane), R114 (Dichlorotetrafluorethane) |
| | EOL | EOL | | Energy substitution from incineration | EOL: Halogenated organic emissions to air, R114 (Dichlorotetrafluorethane) |
| AP | Production | Raw Material Extraction | 85% | 49% Linseed oil<br>27% Titanium dioxide<br>16% Jute | Production : Inorganic emissions to air, Ammonia, $NO_x$ , Sulphur dioxide<br>Production : inorganic emissions to fresh water, Hydrogen chloride |
| | | Transport of Raw materials | 13% | Means of transport (truck, container ship) and their fuels | |
| | | Manufacturing | 2% | 79% Thermal energy | |
| | Transport | Transport Gate to User | | Means of transport (truck, container ship) and their fuels | Transport & Installation : Inorganic emissions to air, $NO_x$ , Sulphur dioxide |
| | Installation | Installation | | 86% Adhesive | |
| | Use | Use | | 87% Electricity<br>12% Detergent | Use : Inorganic emissions to air, Nitrogen oxides , Sulphur dioxide |
| | EOL | EOL | | Incineration of post-consumer linoleum flooring<br>Energy substitution from incineration | EOL : Inorganic emissions to air, Nitrogen oxide, Sulphur dioxide |
| EP | Production | Raw Material Extraction | 94% | 88% Linseed oil | Production : Inorganic emissions to air, Ammonia, $NO_x$<br>Production : Inorganic emissions to fresh water, Nitrate , Nitrogen organic bounded, Phosphate |
| | | Transport of Raw materials | 5% | Means of transport (truck, container ship) and their fuels | |
| | | Manufacturing | 1% | 74% Thermal energy | |
| | Transport | Transport Gate to User | | Means of transport (truck, container ship) and their fuels | Transport & Installation : Inorganic emissions to air, $NO_x$ |
| | Installation | Installation | | 78% Adhesive<br>20% Incineration of waste | |
| | Use | Use | | 64% Electricity<br>35% Detergent and waste water treatment | Use : Inorganic emissions to air, $NO_x$ |
| | EOL | EOL | | Incineration of post-consumer linoleum flooring<br>Energy substitution from incineration | EOL : Inorganic emissions to air, $NO_x$ |
| POCP | Production | Raw Material Extraction | 80% | 48% Linseed oil<br>24% Titanium dioxide<br>14% Jute | Production : Inorganic emissions to air, Carbon monoxide, $NO_x$ , Sulphur dioxide<br>Production : Group NMVOC to air, NMVOC (unspecified) |
| | | Transport of Raw materials | 13% | Means of transport (truck, container ship) and their fuels | |
| | | Manufacturing | 7% | 94% Thermal energy | |
| | Transport | Transport | | Means of transport (truck, | Transport & Installation : Inorganic |

| Impact Category | Stage | Module | | Main contributor | Main contributing flows |
|---|---|---|---|---|---|
| | | Gate to User | | container ship) and their fuels | emissions to air, $NO_x$ |
| | Installation | Installation | | 92% Adhesive | Transport & Installation : Group NMVOC to air, NMVOC (unspecified) |
| | Use | Use | | 76% electricity<br>22% Detergent | Use : Inorganic emissions to air, Sulphur dioxide |
| | EOL | EOL | | Energy substitution from incineration | EOL : Inorganic emissions to air, Carbon monoxide , $NO_x$, Sulphur dioxide<br>EOL : Group NMVOC to air, NMVOC (unspecified) , Methane |
| ADPe | Production | Raw Material Extraction | 92% | 43% Tall oil<br>25% Titanium dioxide<br>15% Linseed oil | Production : Nonrenewable elements, Copper, Lead, Phosphorus<br>Production : Nonrenewable resources, Sodium chloride (Rock salt) |
| | | Transport of Raw materials | <0,5% | Means of transport (truck, container ship) and their fuels | |
| | | Manufacturing | 8% | 53% Electricity<br>21% Thermal energy<br>26% Packaging | |
| | Transport | Transport Gate to User | | Means of transport (truck, container ship) and their fuels | Transport & Installation : Non renewable resources, Lead-zinc ore |
| | Installation | Installation | | 95% Adhesive | |
| | Use | Use | | 69% Electricity<br>28% Detergent | Use : Nonrenewable resources, Sodium chloride (Rock salt) |
| | EOL | EOL | | Incineration of post-consumer linoleum flooring<br>Energy substitution from incineration | EOl : Nonrenewable resources, Sodium chloride (Rock salt)<br>EOL : Nonrenewable elements, Silver, Copper, Lead |
| ADPf | Production | Raw Material Extraction | 60% | 41% Linseed oil<br>24% Jute<br>17% Tall oil | Production : Crude oil resource, Crude oil (in MJ)<br>Production : Hard coal resource, hard coal (in MJ)<br>Production : Natural gas (resource), Natural gas (in MJ) |
| | | Transport of Raw materials | 3% | Means of transport (truck, container ship) and their fuels | |
| | | Manufacturing | 37% | 98% Thermal energy | |
| | Transport | Transport Gate to User | | Means of transport (truck, container ship) and their fuels | Transport & Installation : Crude oil resource, Crude oil (in MJ)<br>Transport & Installation : Natural gas (resource), Natural gas (in MJ) |
| | Installation | Installation | | 99% Adhesive | |
| | Use | Use | | 70% electricity<br>30% Detergent | Use : Hard coal resource, hard coal (in MJ), Natural gas (in MJ) |
| | EOL | EOL | | Energy substitution from incineration | EOL : Natural gas (resource), Natural gas (in MJ) |
| Ecotoxicity | Production | Raw Material Extraction | 41% | 48% Linseed oil<br>17% Jute hessian<br>9% Titanium dioxide<br>13% Lacquer | Production : Hydrocarbons to fresh water, Anthracene, Phenol (Hydroxy benzene), Methanol |
| | | Transport of Raw materials | 23% | Means of transport (truck, container ship) and their fuels | |
| | | Manufacturing | 36% | 56% Packaging end product<br>43% Thermal energy | |
| | Transport | Transport Gate to User | | Means of transport (truck, container ship) and their fuels | Transport & installation : Hydrocarbons to fresh water, Anthracene, Phenol (Hydroxy benzene), Methanol |
| | Installation | Installation | | 98% Adhesive | |
| | Use | Use | | 11% Detergent<br>88% Electricity | Use : Hydrocarbons to fresh water, Anthracene, Phenol (Hydroxy benzene), Methanol |
| | EOL | EOL | | Energy substitution from incineration | EOL : Hydrocarbons to fresh water, Anthracene, Phenol (Hydroxy benzene), |

| Impact Category | Stage | Module | | Main contributor | Main contributing flows |
|---|---|---|---|---|---|
| | | | | | Methanol |
| Human toxicity, cancer | Production | Raw Material Extraction | 15% | 17% Linseed oil<br>45% Jute<br>18% Tall oil<br>9% Titanium dioxide | Production : Group NMVOC to air, NMVOC (unspecified), Formaldehyde (Methanal) |
| | | Transport of Raw materials | 1% | Means of transport (truck, container ship) and their fuels | |
| | | Manufacturing | 84% | 53% Thermal energy<br>47% Electricity (Hydropower) | |
| | Transport | Transport Gate to User | | Means of transport (truck, container ship) and their fuels | Transport & Installation : Group NMVOC to air, NMVOC (unspecified), Formaldehyde (Methanal) |
| | Installation | Installation | | 97% adhesive | |
| | Use | Use | | 93% Electricity | Use : Group NMVOC to air, NMVOC (unspecified), Formaldehyde (Methanal) |
| | EOL | EOL | | Energy substitution from incineration | EOL : Group NMVOC to air, NMVOC (unspecified), Formaldehyde (Methanal) |
| Human toxicity, non canc. | Production | Raw Material Extraction | 77% | 65% Lacquer<br>12% Linseed oil<br>10% Jute | Production : Group NMVOC to air, NMVOC (unspecified), Methyl Methacrylate (MMA) |
| | | Transport of Raw materials | 1% | Means of transport (truck, container ship) and their fuels | |
| | | Manufacturing | 22% | 99% Thermal energy | |
| | Transport | Transport Gate to User | | Means of transport (truck, container ship) and their fuels | Transport & Installation : Group NMVOC to air, NMVOC (unspecified), Hexane, Methyl Methacrylate (MMA) |
| | Installation | Installation | | 100% adhesive | |
| | Use | Use | | 77% electricity<br>23% Detergent | Use : Group NMVOC to air, NMVOC (unspecified), Xylene, Formaldehyde (Methanal) |
| | EOL | EOL | | Energy substitution from incineration | EOL : Group NMVOC to air, NMVOC (unspecified), Formaldehyde (Methanal), Xylene |

## Description of Selected Impact Categories

### Abiotic Depletion Potential

The abiotic depletion potential covers all natural resources such as metal containing ores, crude oil and mineral raw materials. Abiotic resources include all raw materials from non-living resources that are non-renewable. This impact category describes the reduction of the global amount of non-renewable raw materials. Non-renewable means a time frame of at least 500 years. This impact category covers an evaluation of the availability of natural elements in general, as well as the availability of fossil energy carriers.

ADP (elements) describes the quantity of non-energetic resources directly withdrawn from the geosphere. It reflects the scarcity of the materials in the geosphere and is expressed in Antimony equivalents. The characterization factors are published by the CML, Oers 2010.

Are fossil energy carriers included in the impact category, it is ADP (fossil). Fossil fuels are used similarly to the primary energy consumption; the unit is therefore also MJ. In contrast to the primary fossil energy ADP fossil does not contain uranium, because this does not count as a fossil fuel.

### Primary energy consumption

Primary energy demand is often difficult to determine due to the various types of energy source. Primary energy demand is the quantity of energy directly withdrawn from the hydrosphere, atmosphere or geosphere or energy source without any anthropogenic change. For fossil fuels and uranium, this would be the amount of resource withdrawn expressed in its energy equivalent (i.e. the energy content of the raw material). For renewable resources, the energy-characterized amount of biomass consumed would be described. For hydropower, it would be based on the amount of energy that is gained from the change in the potential energy of water (i.e. from the height difference). As aggregated values, the following primary energies are designated:

The total **"Primary energy consumption non-renewable"**, given in MJ, essentially characterizes the gain from the energy sources natural gas, crude oil, lignite, coal and uranium. Natural gas and crude oil will both be used for energy production and as material constituents e.g. in plastics. Coal will primarily be used for energy production. Uranium will only be used for electricity production in nuclear power stations.

The total **"Primary energy consumption renewable"**, given in MJ, is generally accounted separately and comprises hydropower, wind power, solar energy and biomass. It is important that the end energy (e.g. 1 kWh of electricity) and the primary energy used are not miscalculated with each other; otherwise the efficiency for production or supply of the end energy will not be accounted for. The energy content of the manufactured products will be considered as feedstock energy content. It will be characterised by the net calorific value of the product. It represents the still usable energy content.

### Waste categories

There are various different qualities of waste. For example, waste can be classed according to German and European waste directives. The modelling principles have changed with the last GaBi4 database update in October 2006. Now all LCA data sets (electricity generation, raw material etc.) already contain the treatment of the waste with very low waste output at the end of the stage. So the amount of waste is predominantly caused by foreground processes during the production phase. This is important for the interpretation of waste amounts.

From a balancing point of view, it makes sense to divide waste into three categories. The categories overburden/tailings, industrial waste for municipal disposal and hazardous waste will be used.

**Overburden / tailings** in kg: This category consists of the layer which must be removed in order to access raw material extraction, ash and other raw material extraction conditional materials for disposal. Also included in this category are tailings such as inert rock, slag, red mud etc.

**Industrial waste for municipal disposal** in kg: This term contains the aggregated values of industrial waste for municipal waste according to 3. AbfVwV TA SiedlABf.

**Hazardous waste** in kg: This category includes materials that will be treated in a hazardous waste incinerator or hazardous waste landfill, such as painting sludges, galvanic sludges, filter dusts or other solid or liquid hazardous waste and radioactive waste from the operation of nuclear power plants and fuel rod production.

## Global Warming Potential (GWP)

The mechanism of the greenhouse effect can be observed on a small scale, as the name suggests, in a greenhouse. These effects are also occurring on a global scale. The occurring short-wave radiation from the sun comes into contact with the earth's surface and is partly absorbed (leading to direct warming) and partly reflected as infrared radiation. The reflected part is absorbed by so-called greenhouse gases in the troposphere and is re-radiated in all directions, including back to earth. This results in a warming effect on the earth's surface.

In addition to the natural mechanism, the greenhouse effect is enhanced by human activities. Greenhouse gases that are considered to be caused, or increased, anthropogenically are, for example, carbon dioxide, methane and CFCs. *Figure A1* shows the main processes of the anthropogenic greenhouse effect. An analysis of the greenhouse effect should consider the possible long term global effects.

The global warming potential is calculated in carbon dioxide equivalents ($CO_2$-Eq.). This means that the greenhouse potential of an emission is given in relation to $CO_2$. Since the residence time of the gases in the atmosphere is incorporated into the calculation, a time range for the assessment must also be specified. A period of 100 years is customary.

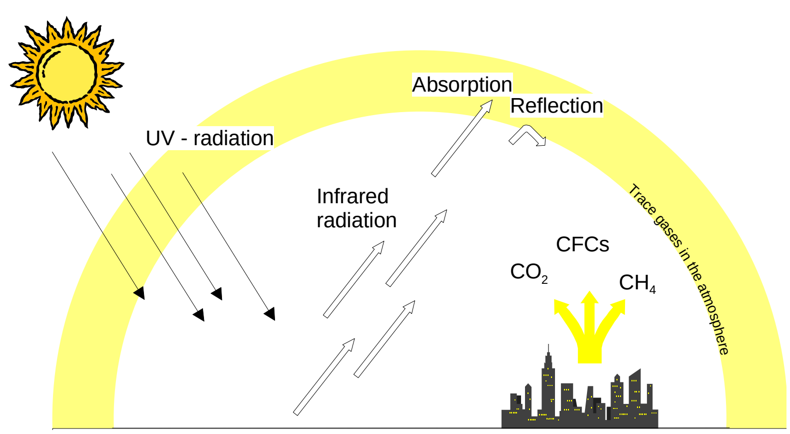



*Figure A1: Greenhouse effect (KREISSIG 1999)*

## Acidification Potential (AP)

The acidification of soils and waters predominantly occurs through the transformation of air pollutants into acids. This leads to a decrease in the pH-value of rainwater and fog from 5.6 to 4 and below. Sulphur dioxide and nitrogen oxide and their respective acids ($H_2SO_4$ and $HNO_3$) produce relevant contributions. This damages ecosystems, whereby forest dieback is the most well-known impact.

Acidification has direct and indirect damaging effects (such as nutrients being elutriated from soils or an increased solubility of metals into soils). But even buildings and building materials can be damaged. Examples include metals and natural stones which are corroded or disintegrated at an increased rate.

When analysing acidification, it should be considered that although it is a global problem, the regional effects of acidification can vary. *Figure A2* displays the primary impact pathways of acidification.

The acidification potential is given in sulphur dioxide equivalents (SO2-Eq.). The acidification potential is described as the ability of certain substances to build and release H+ - ions. Certain emissions can also be considered to have an acidification potential, if the given S-, N- and halogen atoms are set in proportion to the molecular mass of the emission. The reference substance is sulphur dioxide.

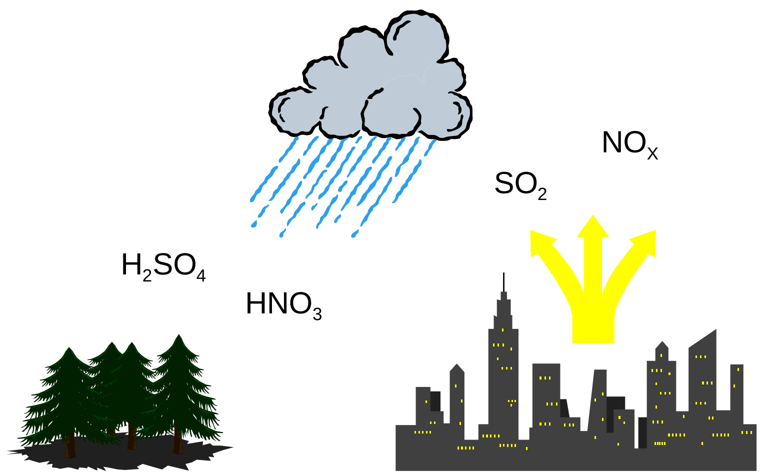



*Figure A2: Acidification Potential (KREISSIG 1999)*

## Eutrophication Potential (EP)

Eutrophication is the enrichment of nutrients in a certain place. Eutrophication can be aquatic or terrestrial. Air pollutants, waste water and fertilization in agriculture all contribute to eutrophication.

The result in water is an accelerated algae growth, which in turn, prevents sunlight from reaching the lower depths. This leads to a decrease in photosynthesis and less oxygen production. In addition, oxygen is needed for the decomposition of dead algae. Both effects cause a decreased oxygen concentration in the water, which can eventually lead to fish dying and to anaerobic decomposition (decomposition without the presence of oxygen). Hydrogen sulphide and methane are thereby produced. This can lead, among others, to the destruction of the eco-system.

On eutrophicated soils, an increased susceptibility of plants to diseases and pests is often observed, as is a degradation of plant stability. If the nutrification level exceeds the amounts of nitrogen necessary for a maximum harvest, it can lead to an enrichment of nitrate. This can cause, by means of leaching, increased nitrate content in groundwater. Nitrate also ends up in drinking water.

Nitrate at low levels is harmless from a toxicological point of view. However, nitrite, a reaction product of nitrate, is toxic to humans. The causes of eutrophication are displayed in Figure A3. The eutrophication potential is calculated in phosphate equivalents (PO4-Eq). As with acidification potential, it's important to remember that the effects of eutrophication potential differ regionally.

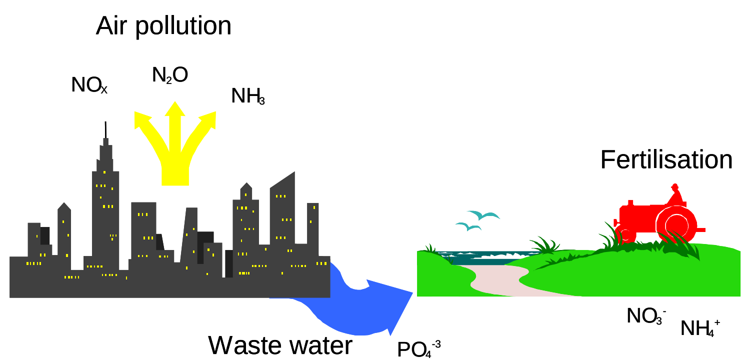



*Figure A3: Eutrophication Potential (KREISSIG 1999)*

## Photochemical Ozone Creation Potential (POCP)

Despite playing a protective role in the stratosphere, at ground-level ozone is classified as a damaging trace gas. Photochemical ozone production in the troposphere, also known as summer smog, is suspected to damage vegetation and material. High concentrations of ozone are toxic to humans.

Radiation from the sun and the presence of nitrogen oxides and hydrocarbons incur complex chemical reactions, producing aggressive reaction products, one of which is ozone. Nitrogen oxides alone do not cause high ozone concentration levels. Hydrocarbon emissions occur from incomplete combustion, in conjunction with petrol (storage, turnover, refueling etc.) or from solvents. High concentrations of ozone arise when the temperature is high, humidity is low, when air is relatively static and when there are high concentrations of hydrocarbons. Today it is assumed that the existance of NO and CO reduces the accumulated ozone to $NO_2$, $CO_2$ and $O_2$. This means, that high concentrations of ozone do not often occur near hydrocarbon emission sources. Higher ozone concentrations more commonly arise in areas of clean air, such as forests, where there is less NO and CO (*Figure A4*).

In Life Cycle Assessments, photochemical ozone creation potential (POCP) is referred to in ethylene-equivalents ($C_2H_4$-Eq.). When analyzing, it's important to remember that the actual ozone concentration is strongly influenced by the weather and by the characteristics of the local conditions.

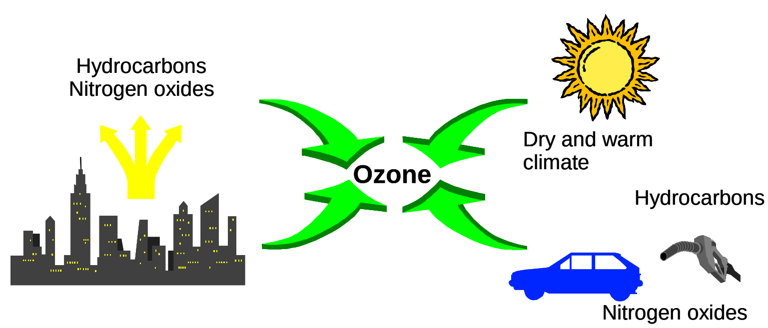



*Figure A4: Photochemical Ozone Creation Potential*

## Ozone Depletion Potential (ODP)

Ozone is created in the stratosphere by the disassociation of oxygen atoms that are exposed to short-wave UV-light. This leads to the formation of the so-called ozone layer in the stratosphere (15 - 50 km high). About 10 % of this ozone reaches the troposphere through mixing processes. In spite of its minimal concentration, the ozone layer is essential for life on earth. Ozone absorbs the short-wave UV-radiation and releases it in longer wavelengths. As a result, only a small part of the UV-radiation reaches the earth.

Anthropogenic emissions deplete ozone. This is well-known from reports on the hole in the ozone layer. The hole is currently confined to the region above Antarctica, however another ozone depletion can be identified, albeit not to the same extent, over the mid-latitudes (e.g. Europe). The substances which have a depleting effect on the ozone can essentially be divided into two groups; the fluorine-chlorine-hydrocarbons (CFCs) and the nitrogen oxides (NOX). *Figure A5* depicts the procedure of ozone depletion.

One effect of ozone depletion is the warming of the earth's surface. The sensitivity of humans, animals and plants to UV-B and UV-A radiation is of particular importance. Possible effects are changes in growth or a decrease in harvest crops (disruption of photosynthesis), indications of tumors (skin cancer and eye diseases) and decrease of sea plankton, which would strongly affect the food chain. In calculating the ozone depletion potential, the anthropogenically released halogenated hydrocarbons, which can destroy many ozone molecules, are recorded first. The so-called Ozone Depletion Potential (ODP) results from the calculation of the potential of different ozone relevant substances.

This is done by calculating, first of all, a scenario for a fixed quantity of emissions of a CFC reference (CFC 11). This results in an equilibrium state of total ozone reduction. The same scenario is considered for each substance under study whereby CFC 11 is replaced by the quantity of the substance. This leads to the ozone depletion potential for each respective substance, which is given in CFC 11 equivalents. An evaluation of the ozone depletion potential should take the long term, global and partly irreversible effects into consideration.

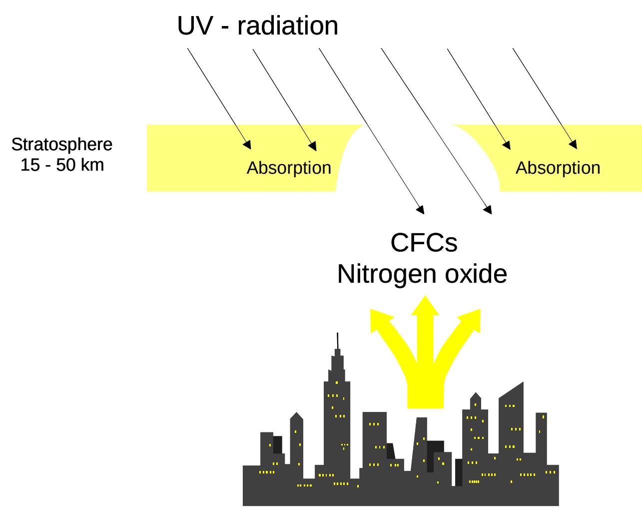



*Figure A5: Ozone Depletion Potential (KREISSIG 1999)*

## References



| | |
|---|---|
| GaBi 9 2012 | THINKSTEP AG; GaBi 9: Software-System and Database for Life Cycle Engineering. Copyright, TM. Stuttgart, Echterdingen, 1992-2017. |
| GaBi 9 2012D | GaBi 9: Documentation of GaBi 9: Software-System and Database for Life Cycle Engineering. Copyright, TM. Stuttgart, Echterdingen, 1992-2017. http://documentation.gabi-software.com/ |
| UL Environment | UL Environment's Program Operator Rules |
| PE 2012 | Description of Selected Impact Categories, Thinkstep AG, 2012 |
| ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance | European Commission-Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook- Recommendations for Life Cycle Impact Assessment in the European context. First edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union; 2011 |
| **Standards and Laws** | |
| DIN EN ISO 14044 | Environmental management - Life cycle assessment - Requirements and guidelines (ISO 14044:2006); English version EN ISO 14044 |
| ISO 14025 2006 | EN ISO 14025: Environmental labels and declarations — Type III environmental declarations — Principles and procedures |
| ISO 14040 2006 | Environmental management - Life cycle assessment - Principles and framework (ISO 14040); English version EN ISO 14040 |
| CEN/TR 15941 | Sustainability of construction works - Environmental product declarations - Methodology for selection and use of generic data; German version CEN/TR 15941 |
| EN 16810 | Resilient, textile and laminate floor coverings - Environmental product declarations - Product category rules |
| CPR | REGULATION (EU) No 305/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC |
| EN-ISO 10874 | Resilient, textile and laminate floor coverings – Classification |