

ENVIRONMENTAL PRODUCT DECLARATION

MARMOLEUM DECIBEL

FORBO FLOORING SYSTEMS
RESILIENT LINOLEUM FLOOR COVERING

Marmoleum Decibel



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



ENVIRONMENTAL PRODUCT DECLARATION



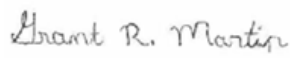
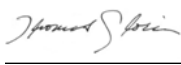
FLOORING SYSTEMS

Marmoleum Decibel
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.



PROGRAM OPERATOR	UL Environment 333 Pfingsten Road Northbrook, IL 60611	
DECLARATION HOLDER	Forbo Flooring B.V. Industrieweg 12 P.O. Box 13 NL-1560 AA Krommenie	
DECLARATION NUMBER	4788294459.114.1	
DECLARED PRODUCT	Marmoleum Decibel Resilient Linoleum Floor Covering	
REFERENCE PCR	EN 16810: Resilient, Textile and Laminate floor coverings – Environmental product declarations – Product category rules	
DATE OF ISSUE	August 2, 2018	
PERIOD OF VALIDITY	5 Years	
CONTENTS OF THE DECLARATION	Product definition and information about building physics Information about basic material and the material's origin Description of the product's manufacture Indication of product processing Information about the in-use conditions Life cycle assessment results 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 <input type="checkbox"/> INTERNAL <input checked="" type="checkbox"/> 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

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Product Definition

Product Classification and description

Marmoleum is a resilient floor covering complying with all the requirements of EN 686 Resilient floor coverings - Specification for plain and decorative linoleum on a foam backing. Marmoleum is made from natural raw materials making it preferable ecological 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 and limestone.

Marmoleum Decibel provides the highest reduction of impact sound by 18 dB. It is a 3.5 mm thick Marmoleum Real laminated onto a 1 mm layer of polyolefin foam.

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 Decibel of 3.5 mm nominal thickness.

Marmoleum Decibel is build up in 4 layers as illustrated in figure 1. The three Marmoleum layers form one homogeneous product by the cross linking bondings formed during the oxidative curing process. The polyolefin foam is laminated under the Marmoleum :

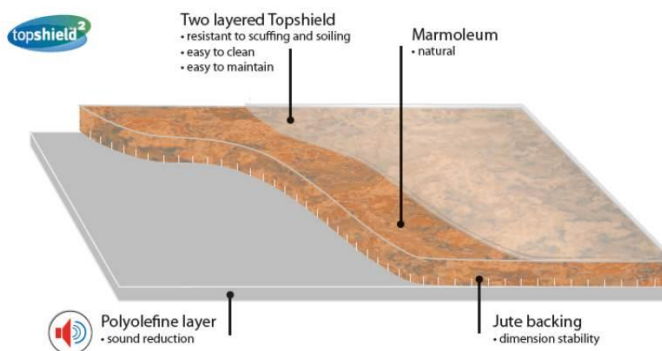


Figure 1: Illustration of Marmoleum

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 polyester backing.
3. **Backing:** The backing is woven jute.
4. **Foam layer:** Polyolefin foam

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

ENVIRONMENTAL PRODUCT DECLARATION





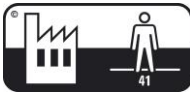
FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Range of application

Marmoleum Decibel is classified in accordance with EN-686 to be installed in the following use areas defined in EN-ISO 10874:

Area of application	Domestic	Commercial	Industrial
	Class 23	Class 33	Class 41
Marmoleum Decibel			

Product Standard

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

- Meets or exceeds all technical requirements in ASTM F 2034 Standard Specification for Linoleum Sheet Flooring.
- Meets or exceeds all technical requirements in EN-686 Resilient floor coverings - Specification for plain and decorative linoleum on a foam backing.



Marmoleum meets the requirements of EN 14041

EN 13501-1	Reaction to fire	C _{fl} - s1
EN 13893	Slip resistance	DS: ≥ 0.30
EN 1815	Body voltage	< 2 kV
EN 12524	Thermal conductivity	0.17 W/mK

Fire Testing:

- 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 C when tested in accordance to ASTM E 84/NFPA 255, Standard Test Method for Surface Burning Characteristics.
- FSC1-150; SD-160 when tested in accordance to CAN/ULC S102.2, Standard Test Method for Flame Spread Rating and Smoke Development.
- Compliant with CHPS 01350 requirements for VOC emissions and indoor air quality.

Emission testing :

- AgBB requirements following EN ISO 16000-9 Indoor Air Emissions : TVOC at 28 days
- French act Grenelle: A+
- Compliant with CHPS 01350 requirements for VOC emissions and indoor air quality



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Accreditation

- ISO 9001 Quality Management System
- ISO 14001 Environmental Management System
- OHSAS 18001 Occupational Health and Safety Management Systems
- SA 8000 Social Accountability standard
- Umweltzeichen
- Nordic Swan Ecolabel



Delivery Status

Table 1: Specification of delivered product

Characteristics	Nominal Value	Unit
Product thickness	3.5	mm
Product Weight	3300	g/m ²
Length x Width	32 x 2	m

Material Content

Material Content of the Product

Table 2: Composition of Marmoleum Decibel

Component	Material	Availability	Amount [%]	Origin
Binder	Linseed oil	Bio based crop	19	USA/Canada/Europe
	Gum rosin	Bio based crop	3	Indonesia/China
	Tall oil	Bio based waste product from paper Industry	6	USA
Filler	Wood flour	Bio based waste product from wood processing	18	Germany
	Calcium carbonate	Abundant mineral	19	Germany
	Reused Marmoleum		22	Internal
Pigment	Titanium dioxide	Limited mineral	1	Global
	Various other pigments	Limited mineral	2	Global
Backing	Jute	Bio based crop	7	India/Bangladesh
	Polyolefin foam	Fossil limited	2	Europe
Finish	Lacquer	Fossil limited	1	Netherlands

Environment



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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.

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.

Reused Marmoleum : Waste material coming from the Marmoleum production which is reused.

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.

Polyolefin foam : A polyolefin is a polymer produced from a simple olefin (also called an alkene with the general formula C_nH_{2n}) as a monomer.

Lacquer : The factory applied lacquer – Topshield 2 – is a waterborne UV cured urethane – acrylate hybrid dispersion.

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Production of the Floor Covering

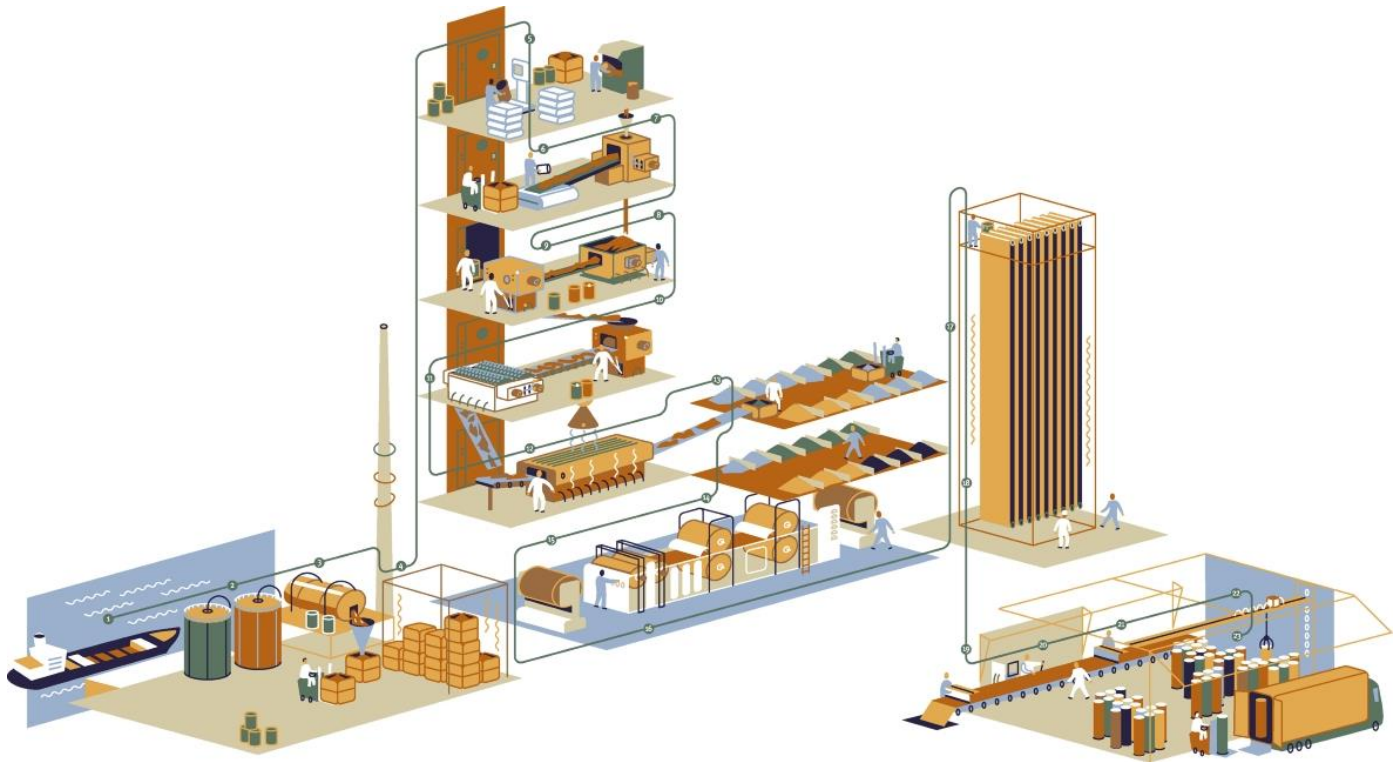


Figure 2: Illustration of the Production process

Marmoleum Decibel 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 polyester 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 foam layer is applied on the backside, 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

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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	694 km
○ Transport distance 7.5t truck (Fine distribution)	257 km
○ Capacity utilization trucks (including empty runs)	85 %
○ Transport distance Ocean ship	4916 km
○ Capacity utilization Ocean ship	48%

Installation

Because of the specific techniques used during the installation of Marmoleum Decibel 5% of the material is cut off as installation waste. For installation of Marmoleum Decibel on the floor a worst case scenario has been modeled (assuming 0.425 kg/m² of adhesive is required). In practice this amount will almost always be lower. 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 Decibel 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 (low) zero emission hard setting adhesives for installing Marmoleum Decibel.

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 Decibel is sold in Europe the European electricity grid mix is used in the calculations for the energy recovery during incineration.

Packaging

Cardboard tubes, PE-film and wooden pallets 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

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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 Neutral detergent

For the calculations the following cleaning regime is considered:

- Dry cleaning with a 1.5 kW vacuum cleaner for 0.21 min/m², twice a week. This equates to 0.55 kWh/m²*year.
- Once a week wet cleaning with 0.062 l/m² water and 0.0008 kg/m² detergent. This result in the use of 3.224 l/m²*year water and 0.04 kg/m²*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

Marmoleum Decibel is complying with:

- o AgBB requirements
- o French act Grenelle: A+
- o CHPS section 01350

End of Life

The deconstruction of installed Marmoleum Decibel 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 Decibel is sold are having a non landfill policy. Because of the high calorific value of Marmoleum Decibel 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)

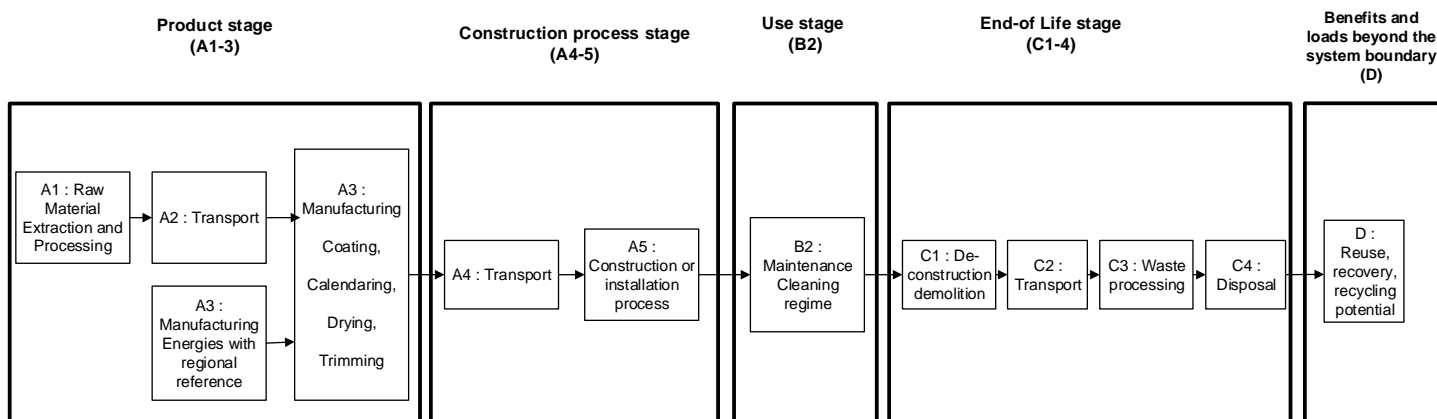


Figure 3: Flow chart of the Life Cycle Assessment

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.

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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 6 Software System for Life Cycle Engineering, developed by THINKSTEP AG has been used. All relevant LCA datasets are taken from the GaBi 6 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 2017). 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

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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 6 Software System for Life Cycle Engineering, developed by THINKSTEP AG, is used. All relevant LCA datasets are taken from the GaBi 6 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 Kirkcaldy, United Kingdom. The GaBi 6 Hydropower, Wind-power and Biomass dataset for the United Kingdom have therefore been used (reference year 2016). The energy supplier is providing Forbo with a certificate every year.

CO₂-Certificates

No CO₂-certificates are considered in this study.

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Life Cycle Inventory Analysis

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

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

Impact Category : CML 2001 – Jan. 2016	Marmoleum Decibel	Unit
Global Warming Potential (GWP 100 years)	7,90E+00	kg CO ₂ -Equiv.
Ozone Layer Depletion Potential (ODP. steady state)	2,08E-08	kg R11-Equiv.
Acidification Potential (AP)	4,55E-02	kg SO ₂ -Equiv.
Eutrophication Potential (EP)	1,22E-02	kg Phosphate-Equiv.
Photochem. Ozone Creation Potential (POCP)	1,78E-03	kg Ethene-Equiv.
Abiotic Depletion Potential Elements (ADPE)	4,35E-06	kg Sb-Equiv.
Abiotic Depletion Potential Fossil (ADPF)	8,82E+01	[MJ]

Table 4: Results of the LCA – Environmental impact for Marmoleum Decibel (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.]	8,15E-01	6,92E-01	8,26E-01	3,16E-01	2,52E-01	2,28E-02	5,89E+00	-9,15E-01
ODP	[kg CFC11-Eq.]	1,84E-08	1,17E-14	3,77E-10	2,06E-09	1,12E-12	6,21E-16	1,24E-13	-2,01E-12
AP	[kg SO ₂ -Eq.]	3,43E-02	8,27E-03	1,01E-03	7,82E-04	7,16E-04	5,53E-05	1,93E-03	-1,55E-03
EP	[kg PO ₄ ³⁻ - Eq.]	1,06E-02	9,79E-04	1,60E-04	1,07E-04	6,71E-05	1,40E-05	4,82E-04	-1,67E-04
POCP	[kg Ethen Eq.]	1,54E-03	6,15E-05	9,33E-05	5,51E-05	4,48E-05	-1,91E-05	1,23E-04	-1,21E-04
ADPE	[kg Sb Eq.]	4,13E-06	2,54E-08	1,03E-07	1,58E-07	1,34E-07	1,87E-09	6,14E-08	-2,61E-07
ADPF	[MJ]	7,73E+01	6,16E+00	9,42E+00	3,53E+00	2,68E+00	3,09E-01	1,42E+00	-1,26E+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

ENVIRONMENTAL PRODUCT DECLARATION



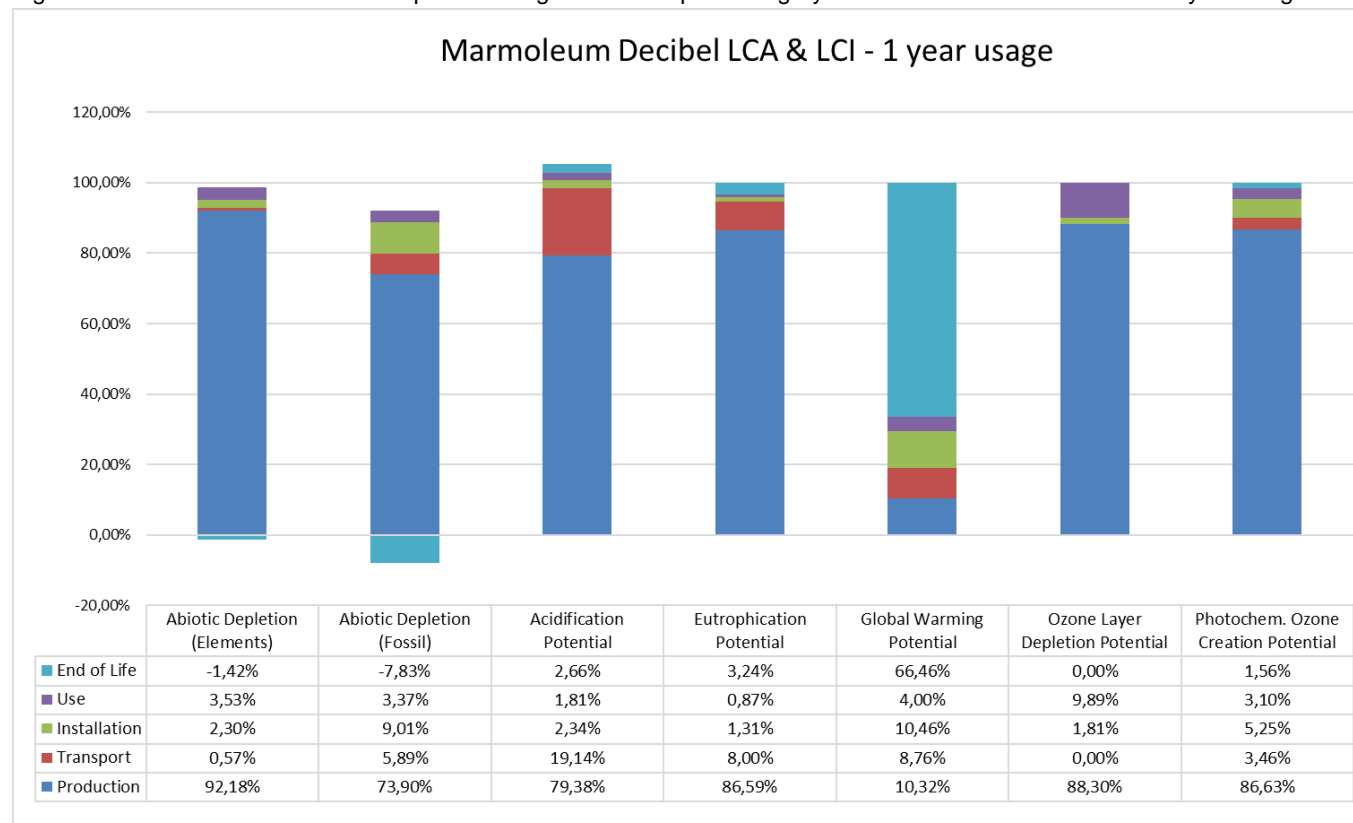
FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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

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



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 Decibel, in particular linseed oil. 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. In comparison with the other environmental impacts the production stage of Marmoleum Decibel has a significant lower impact on the total life cycle caused by the fact that CO₂ is absorbed during the growth of the flax plant.

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

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

and processing with a share of 57-100% of total impacts from the production stage.

Forbo declares in the EPD a worldwide distribution by truck (951 km) and container ship (4916 km). For this scenario the transport has a relevance of 3½%-19% in the impact categories GWP, AP, EP, POCP and ADPF.

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 Decibel (one year)

Parameter	Unit	Manufacturing	Installation		Use (1yr)	End of Life			Credits
		A1-3	A4	A5	B2	C1	C2	C3	D
PERE	[MJ]	3,56E+01	-	-	-	-	-	-	-
PERM	[MJ]	4,73E+01	-	-	-	-	-	-	-
PERT	[MJ]	8,29E+01	1,83E-01	3,45E-01	1,58E+00	1,73E+00	1,71E-02	2,18E-01	-3,12E+00
PENRE	[MJ]	8,09E+01	-	-	-	-	-	-	-
PENRM	[MJ]	0,00E+00	-	-	-	-	-	-	-
PENRT	[MJ]	8,09E+01	6,18E+00	9,64E+00	5,40E+00	4,61E+00	3,11E-01	1,64E+00	-1,60E+01
SM	[kg]	6,46E-01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
RSF	[MJ]	3,16E-09	1,70E-29	4,12E-21	3,48E-24	0,00E+00	1,68E-30	2,04E-23	0,00E+00
NRSF	[MJ]	3,71E-08	2,59E-28	4,84E-20	4,09E-23	6,84E-30	2,54E-29	2,40E-22	-1,23E-29
FW	[m³]	5,47E-02	3,39E-04	2,45E-03	2,38E-03	2,36E-03	3,16E-05	1,35E-02	-4,25E-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



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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 Decibel (one year)

Parameter	Unit	Manufacturing	Transport	Installation	Use (1yr)	End of Life/credits			
		A1-3	A4	A5	B2	C1	C2	C3	D
HWD	[kg]	8,67E-08	1,83E-07	3,99E-09	2,17E-09	2,16E-09	1,80E-08	9,24E-10	-6,54E-09
NHWD	[kg]	5,47E-01	2,83E-04	4,56E-03	1,30E-02	3,24E-03	2,60E-05	1,25E-02	-6,91E-03
RWD	[kg]	1,19E-03	7,93E-06	8,80E-05	7,17E-04	7,63E-04	4,25E-07	8,69E-05	-1,37E-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	5,10E-01	0,00E+00	0,00E+00	0,00E+00	6,71E+00	0,00E+00
EE Thermal energy	[MJ]	0,00E+00	0,00E+00	9,09E-01	0,00E+00	0,00E+00	0,00E+00	1,19E+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 transparent 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 USEtox™ 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. USEtox™ 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 Decibel

Impact Category : USEtox	Marmoleum Decibel	Unit
Eco toxicity	4,72E-03	PAF m3.day
Human toxicity, cancer	6,45E-08	Cases
Human toxicity, non-canc.	8,67E-11	Cases

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

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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

Parameter	Unit	Manufacturing	Transport	Installation	Use (1yr)	End of Life/credits			
		A1-3	A4	A5	B2	C1	C2	C3	D
Eco toxicity	PAF m3.day	2,02E-03	1,43E-03	9,70E-04	4,43E-04	4,29E-04	7,28E-05	1,93E-04	-8,30E-04
Human toxicity, cancer	cases	6,45E-08	1,31E-12	1,72E-11	1,23E-11	1,14E-11	7,13E-14	4,69E-12	-5,80E-11
Human toxicity, non-canc.	cases	2,44E-11	5,31E-13	6,18E-11	7,13E-13	5,94E-13	3,46E-14	3,45E-13	-1,66E-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.

For Eco-toxicity the biggest impact category is the production stage in which the raw material extraction is having a share of 52%. Also the transportation of the raw materials contributes significantly to the total, mainly caused by the materials transported by ocean ships.

The same can be seen for the transportation of Marmoleum Decibel to the customers, a big share is coming from the ocean ships used for transportation with an average distance of 4916 km. Main contributor for the installation is the adhesive and in the use stage most impact is coming from the electricity used to clean the floor.

For Human toxicity (cancer) the production stage is dominated by the raw material extraction and in particular the production of the polyolefin foam. The other life cycle stages have a negligible impact compared to the production stage.

For Human toxicity (non-canc.) by far the biggest impact of 70% is coming from the installation stage, completely caused by the adhesive used for the installation of Marmoleum Decibel. A smaller but significant contribution to the total impact is coming from production stage where the extraction of the raw materials is having a share of 93%.

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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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
EN 686	Resilient floor coverings - Specification for plain and decorative linoleum on a foam backing
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



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Life Cycle Assessment

Marmoleum Decibel



FLOORING SYSTEMS

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

December 2018

Environment



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
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

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

General

The present LCA study of the company Forbo Flooring, a manufacturer of resilient floor coverings, has been performed by Forbo Flooring under support of PE International and has been conducted according to the requirements of the European Standard following the document "Part A: Calculation Rules for the Life Cycle Assessment and Requirements on the Background Report". The LCA report was sent to verification on 07/31/18

Scope

This document is the LCA report for the "Environmental Product Declaration" (EPD) of "Marmoleum Decibel". 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 Decibel complying with EN 686 Resilient floor coverings - Specification for plain and decorative linoleum on a foam backing.

Manufactured by

Forbo Nairn Ltd.

Fife KY1 2SB

P.O. Box 1, Kirkcaldy

United Kingdom.

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

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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.

They are produced at the following manufacturing site:

Forbo Nairn Ltd.

Fife KY1 2SB

P.O. Box 1, Kirkcaldy

United Kingdom

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Product Definition

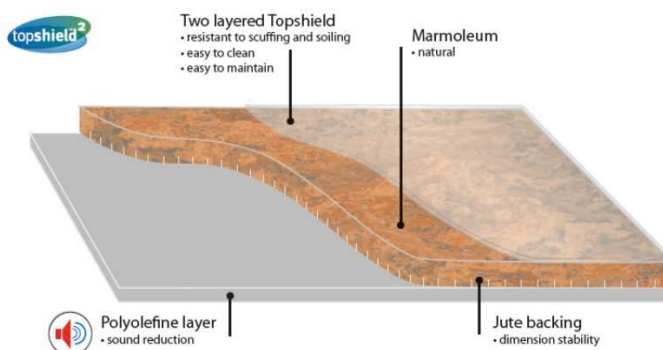
Product Classification and description

Marmoleum is a resilient floor covering complying with all the requirements of EN 686 Resilient floor coverings - Specification for plain and decorative linoleum on a foam backing. Marmoleum is made from natural raw materials making it preferable ecological 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 and limestone.

Marmoleum Decibel provides the highest reduction of impact sound by 18 dB. It is a 3.5 mm thick Marmoleum Real laminated onto a 1 mm layer of polyolefin foam.

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 Decibel of 3.5 mm nominal thickness.

Marmoleum Decibel is build up in 4 layers as illustrated in figure 1. The three Marmoleum layers form one homogeneous product by the cross linking bondings formed during the oxidative curing process. The polyolefin foam is laminated under the Marmoleum :



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 polyester backing.
3. **Backing:** The backing is woven jute.
4. **Foam layer:** Polyolefin foam

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

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Range of application

Marmoleum Decibel is classified in accordance with EN-686 to be installed in the following use areas defined in EN-ISO 10874:

Area of application	Domestic	Commercial	Industrial
	Class 23	Class 33	Class 41
Marmoleum Decibel			

Product Standard

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

- Meets or exceeds all technical requirements in ASTM F 2034 Standard Specification for Linoleum Sheet Flooring.
- Meets or exceeds all technical requirements in EN-686 Resilient floor coverings - Specification for plain and decorative linoleum on a foam backing.



Marmoleum meets the requirements of EN 14041

EN 13501-1	Reaction to fire	C _{fl} - s1
EN 13893	Slip resistance	DS: ≥ 0.30
EN 1815	Body voltage	< 2 kV
EN 12524	Thermal conductivity	0.17 W/mK

Fire Testing:

- 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 C when tested in accordance to ASTM E 84/NFPA 255, Standard Test Method for Surface Burning Characteristics.
- FSC1-150; SD-160 when tested in accordance to CAN/ULC S102.2, Standard Test Method for Flame Spread Rating and Smoke Development.
- Compliant with CHPS 01350 requirements for VOC emissions and indoor air quality.

Emission testing :

- AgBB requirements following EN ISO 16000-9 Indoor Air Emissions : TVOC at 28 days
- French act Grenelle: A+
- Compliant with CHPS 01350 requirements for VOC emissions and indoor air quality



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Accreditation

- ISO 9001 Quality Management System
- ISO 14001 Environmental Management System
- OHSAS 18001 Occupational Health and Safety Management Systems
- SA 8000 Social Accountability standard
- Umweltzeichen
- Nordic Swan Ecolabel

Delivery status

Characteristics	Nominal Value	Unit
Product thickness	3.5	mm
Product Weight	3300	g/m ²
Length x Width	32 x 2	m

Material Content

Component	Material	Availability	Amount [%]	Origin
Binder	Linseed oil	Bio based crop	19	USA/Canada/Europe Indonesia/China USA
	Gum rosin	Bio based crop	3	
	Tall oil	Bio based waste product from paper Industry	6	
Filler	Wood flour	Bio based waste product from wood processing	18	Germany
	Calcium carbonate	Abundant mineral	19	Germany
	Reused Marmoleum		22	Internal
Pigment	Titanium dioxide	Limited mineral	1	Global
	Various other pigments	Limited mineral	2	Global
Backing	Jute	Bio based crop	7	India/Bangladesh
	Polyolefin foam	Fossil limited	2	Europe
Finish	Lacquer	Fossil limited	1	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.

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.

Reused Marmoleum : Waste material coming from the Marmoleum production which is reused.

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

Environment



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

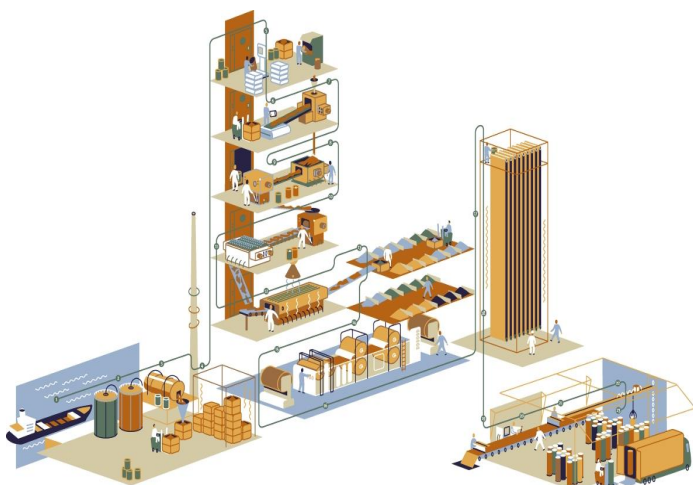
Various other pigments : The vast majority of the used color pigments are iron oxide based.

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.

Polyolefin foam : A polyolefin is a polymer produced from a simple olefin (also called an alkene with the general formula C_nH_{2n}) as a monomer.

Lacquer : The factory applied lacquer – Topshield 2 – is a waterborne UV cured urethane – acrylate hybrid dispersion.

Production of the Floor Covering



Marmoleum Decibel 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 polyester 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 foam layer is applied on the backside, 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.

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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 Decibel is transported as follows:

- | | |
|--|---------|
| ○ Transport distance 40 t truck | 694 km |
| ○ Transport distance 7.5t truck (Fine distribution) | 257 km |
| ○ Capacity utilization trucks (including empty runs) | 85 % |
| ○ Transport distance Ocean ship | 4916 km |
| ○ Capacity utilization Ocean ship | 48% |

Installation

Because of the specific techniques used during the installation of Marmoleum Decibel 6% of the material is cut off as installation waste. For installation of Marmoleum Decibel 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 Decibel 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 (low) zero emission hard setting adhesives for installing Marmoleum Decibels.

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 Decibel is sold in Europe the European electricity grid mix is used in the calculations for the energy recovery during incineration.

Packaging

Cardboard tubes, PE-film and wooden pallets 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.

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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 Neutral detergent

For the calculations the following cleaning regime is considered:

- Dry cleaning with a 1.5 kW vacuum cleaner for 0.21 min/m², twice a week. This equates to 0.55 kWh/m²*year.
- Once a week wet cleaning with 0.062 l/m² water and 0.0008 kg/m² detergent. This result in the use of 3.224 l/m²*year water and 0.04 kg/m²*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

Marmoleum Decibel is complying with:

- o AgBB requirements
- o French Act Grenelle: A+
- o CHPS section 01350

End of Life

The deconstruction of installed Marmoleum Decibel 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 Decibel is sold are having a non landfill policy. Because of the high calorific value of Marmoleum Decibel 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 :

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



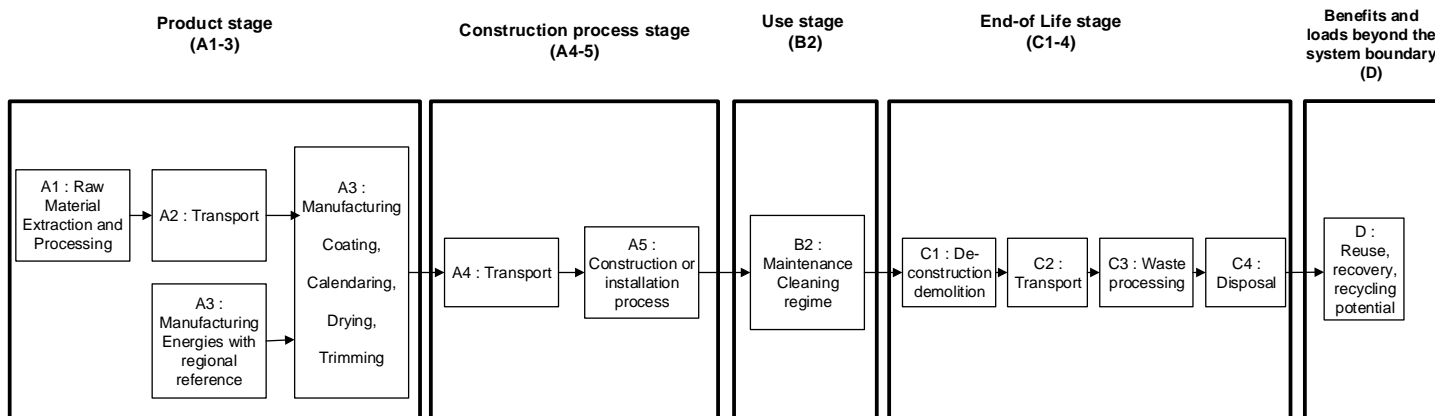


Figure 1 : Flow chart of the Life Cycle Assessment

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.

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 2017). 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 6 Software System for Life Cycle Engineering, developed by THINKSTEP, is used. All relevant LCA datasets are taken from the GaBi 6 software database. The last revision of

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

the used data sets took place within the last 10 years.

Table 1: LCA datasets used in the LCA model

Data set	Region	Reference year
Linseed oil	Germany	2012
Limestone flour	Germany	2017
Tall oil	Europe	2012
Iron oxide	Germany	2012
Pigment	Germany	2007
Titanium dioxide	Europe	2012
Wood flour	Europe	2017
Colophony	France	2012
Polyolefin foam	Europe	2018
Urethane / acrylic hybrid dispersion	Europe	2017
Water (desalinated; deionised)	Germany	2017
Detergent (ammonia based)	Germany	2007
Adhesive for resilient flooring	Germany	2012
Waste incineration of particle board	Europe	2017
Electricity from Hydro power	United Kingdom	2017
Electricity from Wind power	United Kingdom	2017
Power grid mix	Europe	2017
Thermal energy from natural gas	United Kingdom	2017
Thermal energy from natural gas	Europe	2017
Trucks	Global	2017
Municipal waste water treatment (50% agricultural sludge application, 50% sludge incineration).	Germany	2017
Municipal waste water treatment (Sludge incineration).	Germany	2017
Waste incineration of paper/cardboard	Europe	2016
Container ship	Global	2017
Diesel mix at refinery	Europe	2017
Heavy fuel oil at refinery (1.0wt.% S)	Europe	2017
Corrugated board	Europe	2017
Kraft liner (paper)	Europe	2017
Tap water	Europe	2017

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 Kirkcaldy, United Kingdom. The GaBi 6 Hydropower and Wind-power datasets for the United Kingdom have therefore been used (reference year 2017). The energy supplier is providing Forbo with a certificate every year.

CO₂-Certificates

No CO₂-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.

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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 (2%):

Table 2: Composition of linoleum surface layer

Process data	Unit	Marmoleum Decibel
Limestone flour	kg/m ²	0.44
Linseed oil	kg/m ²	0.47
Iron oxide (Fe ₂ O ₃)	kg/m ²	0.03
Pigment	kg/m ²	0.03
Colophony (rosin)	kg/m ²	0.10
Tall oil (Bio based waste product from paper Industry)	kg/m ²	0.14
Titanium dioxide	kg/m ²	0.03
Wood flour (Bio based waste product from wood processing)	kg/m ²	0.60

Table 3: Composition of linoleum intermediate layer

Process data	Unit	Marmoleum Decibel
Limestone	kg/m ²	0.18
Linseed oil	kg/m ²	0.14
Tall oil (Bio based waste product from paper Industry)	kg/m ²	0.07
Linoleum for recycling	kg/m ²	0.70

Table 4: Composition of linoleum substrate layer (same for both products)

Process data	Unit	Marmoleum Decibel
Jute	kg/m ²	0.24
Foam	kg/m ²	0.06

Table 5: Composition of lacquer (same for both products)

Process data	Unit	Marmoleum Decibel
Urethane / acrylic hybrid dispersion	kg/m ²	0.012
Water (desalinated; demonized)	kg/m ²	0.018

Table 6: Production related inputs/outputs

Process data	Unit	Marmoleum Decibel
INPUTS		
Linoleum surface layer	kg	1.85
Linoleum intermediate layer	kg	0.95
Linoleum substrate layer	kg	0.30
Lacquer	kg	0.03
Electricity	MJ	9.14
Thermal energy from natural gas	MJ	24.1
OUTPUTS		
Marmoleum Decibel	kg	3.28
Waste	kg	1.59

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Table 7: Packaging requirements (per m² manufactured product)

Process data	Unit	Marmoleum Decibel
Cardboard tubes	kg	0.030
Packing paper	kg	0.029

Table 8: Transport distances

Process data	Unit	Road	Truck size	Ship
Limestone flour	km	417	14 - 20t gross weight / 11,4t payload capacity	-
Linseed oil	km	212		6330
Iron oxide (Fe ₂ O ₃)	km	220		-
Pigment	km	372		-
Colophony (rosin)	km	226		16700
Tall oil	km	225		5260
Titanium dioxide	km	420		-
Wood flour	km	426		-
Polyolefin foam	km	1500		-
Lacquer	km	225		655
Cardboard tubes	km	700		-
Packing paper	km	1200		-
Wooden pallets	km	145		-
Transport to construction site : -Transport distance 40 t truck	km	951 694	34 - 40 t gross weight / 27t payload capacity 7,5 t - 12t gross weight / 5t payload capacity	4916
-Transport distance 7.5t truck (Fine distribution)		257		
Waste transport to incineration	km	100	7,5 t - 12t gross weight / 5t payload capacity	-

Table 9: Inputs/outputs from Installation

Process data	Unit	Marmoleum Decibel
INPUTS		
Marmoleum Decibel	kg	3.48
Adhesive (30% water content)	kg	0.28
- Water		
- Acrylate co-polymer		
- Styrene Butadiene co-polymer		
- Limestone flour		
- Sand		
OUTPUTS		
Installed Marmoleum Decibel	kg	3.28
Installation Waste	kg	0.20



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Table 10: Inputs from use stage (per m².year of installed product)

Process data	Unit	Marmoleum Decibel
Detergent	kg/year	0.04
Electricity	kWh/year	0.55
Water	kg/year	3.224

Table 11: Disposal

Process data	Unit	Marmoleum Decibel
Post-consumer Marmoleum Decibel to incineration	%	100

Life Cycle Inventory Analysis

In table 12 the environmental impacts for one lifecycle are presented for Marmoleum Decibel. In table 13 the environmental impacts are presented for all the lifecycle stages.

Table 12: Results of the LCA – Environmental impacts one lifecycle (one year) – Marmoleum Decibel 2.0 mm & 2.5 mm

Impact Category : CML 2001 – Nov. 2010	Marmoleum Decibel	Unit
Global Warming Potential (GWP 100 years)	7,90E+00	kg CO ₂ -Equiv.
Ozone Layer Depletion Potential (ODP. steady state)	2,08E-08	kg R11-Equiv.
Acidification Potential (AP)	4,55E-02	kg SO ₂ -Equiv.
Eutrophication Potential (EP)	1,22E-02	kg Phosphate-Equiv.
Photochem. Ozone Creation Potential (POCP)	1,78E-03	kg Ethene-Equiv.
Abiotic Depletion Potential Elements (ADPE)	4,35E-06	kg Sb-Equiv.
Abiotic Depletion Potential Fossil (ADPF)	8,82E+01	[MJ]

Table 13: Results of the LCA – Environmental impact for Marmoleum Decibel (one year)

		Manufacturing	Installation		Use	End of Life			Credits
Parameter	Unit	A1-3	A4	A5	B2	C1	C2	C3	D
GWP	[kg CO ₂ -Equiv.]	8,15E-01	6,92E-01	8,26E-01	3,16E-01	2,52E-01	2,28E-02	5,89E+00	-9,15E-01
ODP	[kg CFC11-Equiv.]	1,84E-08	1,17E-14	3,77E-10	2,06E-09	1,12E-12	6,21E-16	1,24E-13	-2,01E-12
AP	[kg SO ₂ -Equiv.]	3,43E-02	8,27E-03	1,01E-03	7,82E-04	7,16E-04	5,53E-05	1,93E-03	-1,55E-03
EP	[kg PO ₄ ³⁻ -Equiv.]	1,06E-02	9,79E-04	1,60E-04	1,07E-04	6,71E-05	1,40E-05	4,82E-04	-1,67E-04
POCP	[kg Ethen-Equiv.]	1,54E-03	6,15E-05	9,33E-05	5,51E-05	4,48E-05	-1,91E-05	1,23E-04	-1,21E-04
ADPE	[kg Sb-Equiv.]	4,13E-06	2,54E-08	1,03E-07	1,58E-07	1,34E-07	1,87E-09	6,14E-08	-2,61E-07
ADPF	[MJ]	7,73E+01	6,16E+00	9,42E+00	3,53E+00	2,68E+00	3,09E-01	1,42E+00	-1,26E+01
Caption	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 Decibel is shown in figure 2

ENVIRONMENTAL PRODUCT DECLARATION

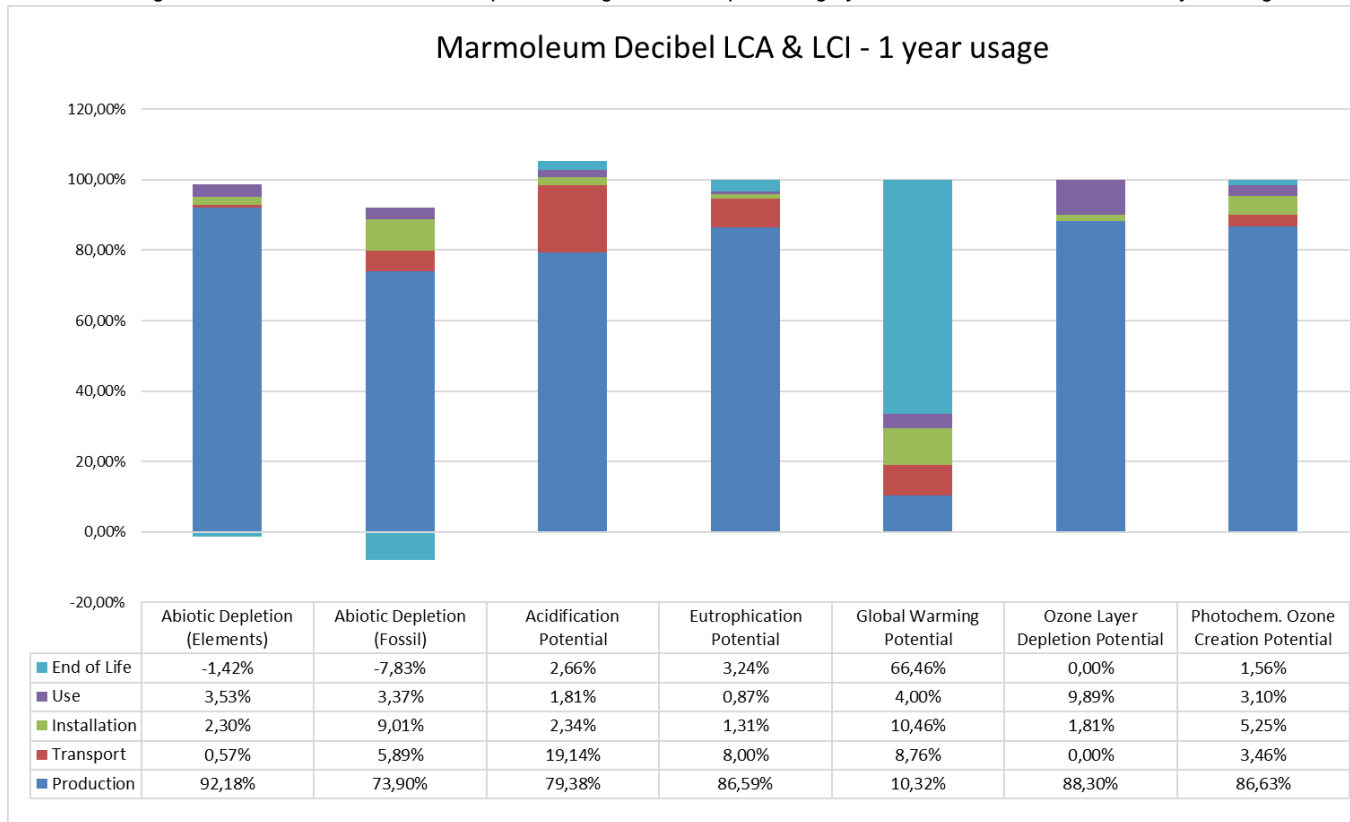


FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Figure 2: relative contribution of each process stage to each impact category for Marmoleum Decibel for a one year usage.



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 Decibel, in particular linseed oil. 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. In comparison with the other environmental impacts the production stage of Marmoleum Decibel has a significant lower impact on the total life cycle caused by the fact that CO₂ is absorbed during the growth of the flax plant.

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 57-100% of total impacts from the production stage.

Forbo declares in the EPD a worldwide distribution by truck (951 km) and container ship (4916 km). For this scenario the transport has a relevance of 3½%-19% in the impact categories GWP, AP, EP, POCP and ADPF.

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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

Table 14: Results of the LCA – Resource use for Marmoleum Decibel (one year)

Parameter	Unit	Manufacturing	Installation		Use (1yr)	End of Life			Credits
		A1-3	A4	A5	B2	C1	C2	C3	D
PERE	[MJ]	3,56E+01	-	-	-	-	-	-	-
PERM	[MJ]	4,73E+01	-	-	-	-	-	-	-
PERT	[MJ]	8,29E+01	1,83E-01	3,45E-01	1,58E+00	1,73E+00	1,71E-02	2,18E-01	-3,12E+00
PENRE	[MJ]	8,09E+01	-	-	-	-	-	-	-
PENRM	[MJ]	0,00E+00	-	-	-	-	-	-	-
PENRT	[MJ]	8,09E+01	6,18E+00	9,64E+00	5,40E+00	4,61E+00	3,11E-01	1,64E+00	-1,60E+01
SM	[kg]	6,46E-01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
RSF	[MJ]	3,16E-09	1,70E-29	4,12E-21	3,48E-24	0,00E+00	1,68E-30	2,04E-23	0,00E+00
NRSF	[MJ]	3,71E-08	2,59E-28	4,84E-20	4,09E-23	6,84E-30	2,54E-29	2,40E-22	-1,23E-29
FW	[m ³]	5,47E-02	3,39E-04	2,45E-03	2,38E-03	2,36E-03	3,16E-05	1,35E-02	-4,25E-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 15 other environmental information describing different waste categories and output flows are presented for all the lifecycle stages.

Table 15: Results of the LCA – Output flows and Waste categories for Marmoleum Decibel (one year)

Parameter	Unit	Manufacturing	Transport	Installation	Use (1yr)	End of Life/credits			
		A1-3	A4	A5	B2	C1	C2	C3	D
HWD	[kg]	8,67E-08	1,83E-07	3,99E-09	2,17E-09	2,16E-09	1,80E-08	9,24E-10	-6,54E-09
NHWD	[kg]	5,47E-01	2,83E-04	4,56E-03	1,30E-02	3,24E-03	2,60E-05	1,25E-02	-6,91E-03
RWD	[kg]	1,19E-03	7,93E-06	8,80E-05	7,17E-04	7,63E-04	4,25E-07	8,69E-05	-1,37E-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	5,10E-01	0,00E+00	0,00E+00	0,00E+00	6,71E+00	0,00E+00
EE Thermal energy	[MJ]	0,00E+00	0,00E+00	9,09E-01	0,00E+00	0,00E+00	0,00E+00	1,19E+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



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Additional Environmental Information

To be fully transparent 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 USEtox™ 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. USEtox™ is classified as Level II / III, unlike for example the CML impact categories which are classified as Level I.

Table 16: Results of the LCA – Environmental impacts one lifecycle (one year) – Marmoleum Decibel

Impact Category : USEtox	Marmoleum Decibel	Unit
Ecotoxicity	4,72E-03	PAF m3.day
Human toxicity, cancer	6,45E-08	Cases
Human toxicity, non-canc.	8,67E-11	Cases

In the following two tables the impacts are subdivided into the lifecycle stages.

Table 17: Results of the LCA – Environmental impact for Marmoleum Decibel (one year)

Parameter	Unit	Manufacturing	Transport	Installation	Use (1yr)	End of Life/credits			
		A1-3	A4	A5	B2	C1	C2	C3	D
Eco toxicity	PAF m3.day	2,02E-03	1,43E-03	9,70E-04	4,43E-04	4,29E-04	7,28E-05	1,93E-04	-8,30E-04
Human toxicity, cancer	cases	6,45E-08	1,31E-12	1,72E-11	1,23E-11	1,14E-11	7,13E-14	4,69E-12	-5,80E-11
Human toxicity, non-canc.	cases	2,44E-11	5,31E-13	6,18E-11	7,13E-13	5,94E-13	3,46E-14	3,45E-13	-1,66E-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.

For Eco-toxicity the biggest impact category is the production stage in which the raw material extraction is having a share of 52%. Also the transportation of the raw materials contributes significantly to the total, mainly caused by the materials transported by ocean ships.

The same can be seen for the transportation of Marmoleum Decibel to the customers, a big share is coming from the



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

ocean ships used for transportation with an average distance of 4916 km. Main contributor for the installation is the adhesive and in the use stage most impact is coming from the electricity used to clean the floor.

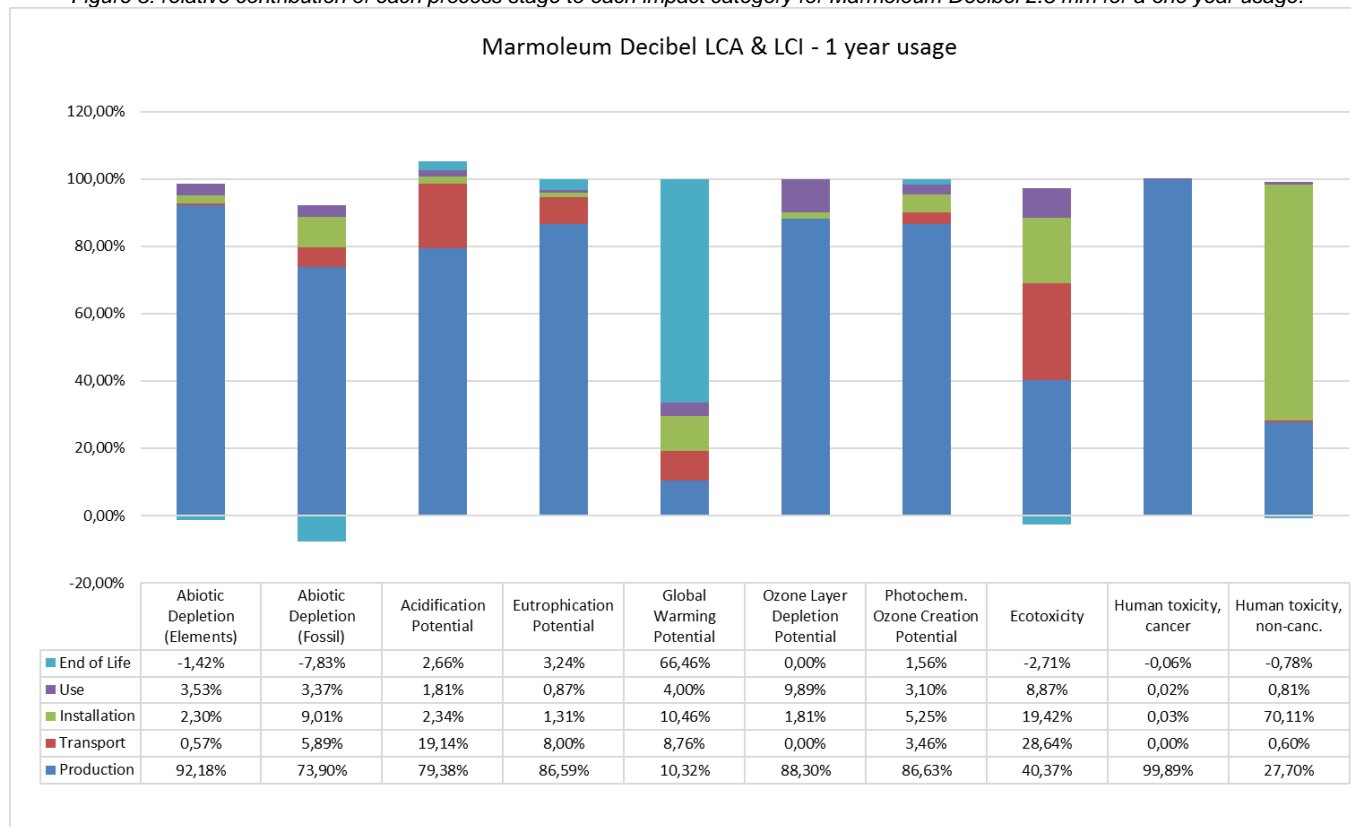
For Human toxicity (cancer) the production stage is dominated by the raw material extraction and in particular the production of the polyolefin foam. The other life cycle stages have a negligible impact compared to the production stage.

For Human toxicity (non-canc.) by far the biggest impact of 70% is coming from the installation stage, completely caused by the adhesive used for the installation of Marmoleum Decibel. A smaller but significant contribution to the total impact is coming from production stage where the extraction of the raw materials is having a share of 93%.

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 figure and table.

Figure 3: relative contribution of each process stage to each impact category for Marmoleum Decibel 2.5 mm for a one year usage.



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Table 18 Main modules and flows contributing to the total impact in each impact category for Marmoleum Decibel 2.5 mm for a one year usage

Impact Category	Stage	Module		Main contributor	Main contributing flows
GWP	Production	Raw Material Extraction	-1.24 kg CO ₂ -equiv.	Linseed oil (-1.79 kg CO ₂ eq.) Titanium dioxide & pigments (0.29 kg CO ₂ eq.) Foam (0.21 kg CO ₂ -eq.)	Production : Renewable resources, Carbon dioxide Production : Inorganic emissions to air, Carbon dioxide
		Transport of Raw materials	0.18 kg CO ₂ -equiv.	Means of transport (truck, container ship) and their fuels	
		Manufacturing	1.87 kg CO ₂ -equiv.	198% Thermal energy (GB)	
	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 47% Installation waste incineration	
	Use	Use		72% Electricity 27% Detergent and waste water treatment	Use : Inorganic emissions to air, Carbon dioxide
	EOL	EOL		Incineration of post-consumer linoleum flooring Energy substitution from incineration	EOL : Inorganic emissions to air, Carbon dioxide
ODP	Production	Raw Material Extraction	100%	26% Tall oil 23% Titanium dioxide & pigment 29% Rosin 18% Linseed oil	Production : Halogenated organic emissions to air, R11 (Trichlorofluoromethane), R114 (Dichlorotetrafluoroethane)
		Transport of Raw materials	< 0.01%	Means of transport (truck, container ship) and their fuels	
		Manufacturing	< 0.01%	98% Packaging	
	Transport	Transport Gate to User		Means of transport (truck, container ship) and their fuels	Transport & Installation : Halogenated organic emissions to air, R114 (Dichlorotetrafluoroethane)
	Installation	Installation		100% Adhesive	
	Use	Use		100% Detergent	Use : Halogenated organic emissions to air, R11 (Trichlorofluoromethane), R114 (Dichlorotetrafluoroethane), R12 (Dichlorofluoromethane)
	EOL	EOL		Energy substitution from incineration	EOL: Halogenated organic emissions to air, R22 (Chlorodifluoromethane)
AP	Production	Raw Material Extraction	86%	57% Linseed oil 19% Titanium dioxide 12% Jute	Production : Inorganic emissions to air, Ammonia, NO _x , Sulphur dioxide Production : inorganic emissions to fresh water, Hydrogen chloride
		Transport of Raw materials	10%	Means of transport (truck, container ship) and their fuels	
		Manufacturing	4%	86% Thermal energy (GB)	
	Transport	Transport Gate to User		Means of transport (truck, container ship) and their fuels	Transport & Installation : Inorganic emissions to air, Ammonia, NO _x , Sulphur dioxide
	Installation	Installation		86% Adhesive	
	Use	Use		83% Electricity 12% Detergent	Use : Inorganic emissions to air, NO _x , Sulphur dioxide
	EOL	EOL		Incineration of post-consumer linoleum flooring Energy substitution from incineration	EOL : Inorganic emissions to air, Ammonia, NO _x , Sulphur dioxide
EP	Production	Raw Material Extraction	94%	89% Linseed oil	Production : Inorganic emissions to air, Ammonia, NO _x
		Transport of	4%	Means of transport (truck,	Production : Inorganic emissions to fresh



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Impact Category	Stage	Module		Main contributor	Main contributing flows
		Raw materials		container ship) and their fuels	water, Nitrate , Nitrogen organic bounded, Phosphate
		Manufacturing	2%	83% Thermal energy (GB)	
	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 20% Installation waste incineration	Transport & Installation : Inorganic emissions to fresh water : Ammonium, Ammonia
	Use	Use		57% Electricity 42% Detergent and waste water treatment	Use : Inorganic emissions to air, NO _x Use : Inorganic emissions to fresh water, Phosphorus
	EOL	EOL		Incineration of post-consumer linoleum flooring Energy substitution from incineration	EOL : Inorganic emissions to air, NO _x , Ammonia
POCP	Production	Raw Material Extraction	83%	51% Linseed oil 16% Titanium dioxide 10% Jute	Production : Inorganic emissions to air, Carbon monoxide, NO _x , Sulphur dioxide Production : Group NMVOC to air, NMVOC (unspecified), Methane, Hexane, Ethane, Butane (n-butene)
		Transport of Raw materials	8.5%	Means of transport (truck, container ship) and their fuels	
		Manufacturing	8.5%	95% Thermal energy (GB)	
	Transport	Transport Gate to User		Means of transport (truck, container ship) and their fuels	Transport & Installation : Inorganic emissions to air, Carbon monoxide, Sulphur dioxide
	Installation	Installation		92% Adhesive	Transport & Installation : Group NMVOC to air, NMVOC (unspecified), Methane, Hexane, Ethane, Butane (n-butene)
	Use	Use		74% electricity 26% Detergent and waste water treatment	Use : Inorganic emissions to air, Sulphur dioxide, NO _x Use : Group NMVOC to air, NMVOC (unspecified), Methane, Hexane, Ethane, Butane (n-butene)
	EOL	EOL		Energy substitution from incineration	EOL : Inorganic emissions to air, Carbon monoxide , NO _x , Sulphur dioxide EOL : Group NMVOC to air, NMVOC (unspecified) , Methane, Hexane, Ethane, Butane (n-butene)
ADPe	Production	Raw Material Extraction	78%	21% Tall oil 12% Titanium dioxide 36% Foam 13% Rosin	Production : Nonrenewable elements, Gold, Copper, Lead, Phosphorus, Molybdenum, Silver Production : Nonrenewable resources, Sodium chloride (Rock salt)
		Transport of Raw materials	<0,3%	Means of transport (truck, container ship) and their fuels	
		Manufacturing	22%	93% Power from Hydro & Wind	
	Transport	Transport Gate to User		Means of transport (truck, container ship) and their fuels	Transport & Installation : Non renewable resources, Sodium chloride (Rock salt)
	Installation	Installation		95% Adhesive	Transport & Installation : Non renewable elements, Lead
	Use	Use		76% Electricity 19% Detergent	Use : Nonrenewable resources, Sodium chloride (Rock salt) Use : Non renewable elements, Chromium, Copper
	EOL	EOL		Incineration of post-consumer linoleum flooring Energy substitution from incineration	EOL : Nonrenewable resources, Sodium chloride (Rock salt) EOL : Nonrenewable elements, Silver, Copper, Lead
ADPf	Production	Raw Material Extraction	57%	39% Linseed oil 15% Jute 14% Titanium dioxide & pigment 10% Tall oil	Production : Crude oil resource, Crude oil (in MJ) Production : Hard coal resource, hard coal (in MJ)



ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

Impact Category	Stage	Module		Main contributor	Main contributing flows
		Transport of Raw materials	3%	Means of transport (truck, container ship) and their fuels	Production : Natural gas (resource), Natural gas (in MJ)
		Manufacturing	40%	98% Thermal energy	
	Transport	Transport Gate to User		Means of transport (truck, container ship) and their fuels	Transport & Installation : Crude oil resource, Transport & Installation : Natural gas (resource),
	Installation	Installation		99% Adhesive	
	Use	Use		69% electricity 30% Detergent	Use : Hard coal resource, hard coal (in MJ) Use : Natural gas resource, Natural gas (in MJ)
	EOL	EOL		Energy substitution from incineration	EOL : Natural gas (resource), Natural gas (in MJ)
Ecotoxicity	Production	Raw Material Extraction	52%	47% Linseed oil 13% Titaniumdioxide & pigment 11% Jute	Production : Hydrocarbons to fresh water, Phenol, Anthracene Production : Pesticides to fresh water, Alachlor
		Transport of Raw materials	28%	Means of transport (truck, container ship) and their fuels	
		Manufacturing	20%	36% Thermal energy (GB) 56% Packaging	
	Transport	Transport Gate to User		Means of transport (truck, container ship) and their fuels	Transport & installation : Hydrocarbons to fresh water, Phenol, Anthracene Transport & installation : Pesticides to fresh water, Alachlor
	Installation	Installation		98% Adhesive	
	Use	Use		10% Detergent 88% Electricity	Use : Hydrocarbons to fresh water, Phenol, Anthracene Use : Pesticides to fresh water, Alachlor
	EOL	EOL		Energy substitution from incineration	EOL : Hydrocarbons to fresh water, Phenol, Anthracene EOL : Pesticides to fresh water, Alachlor
Human toxicity, cancer	Production	Raw Material Extraction	100%	100% Foam	Production : Group NMVOC to air, Formaldehyde (Methanal)
		Transport of Raw materials	< 0.01%	Means of transport (truck, container ship) and their fuels	
		Manufacturing	< 0.2%	98% Thermal energy (GB)	
	Transport	Transport Gate to User		Means of transport (truck, container ship) and their fuels	Transport & Installation : Group NMVOC to air, Formaldehyde (Methanal)
	Installation	Installation		98% adhesive	
	Use	Use		15% Detergent 84% Electricity	Use : Group NMVOC to air, Formaldehyde (Methanal)
	EOL	EOL		Energy substitution from incineration	EOL : Group NMVOC to air, Formaldehyde (Methanal)
Human toxicity, non canc.	Production	Raw Material Extraction	93%	35% Lacquer 40% Foam	Production : Group NMVOC to air, NMVOC (unspecified), Methyl Methacrylate (MMA), Hexane (Isomers), Xylene (Dimethylbenzene)
		Transport of Raw materials	1%	Means of transport (truck, container ship) and their fuels	
		Manufacturing	6%	95% Thermal energy	
	Transport	Transport Gate to User		Means of transport (truck, container ship) and their fuels	Transport & Installation : Group NMVOC to air, Hexane, Methyl Methacrylate (MMA)
	Installation	Installation		100% adhesive	
	Use	Use		76% electricity 24% Detergent and waste water treatment	Use : Group NMVOC to air, Xylene, Formaldehyde
	EOL	EOL		Energy substitution from incineration	EOL : Group NMVOC to air, Formaldehyde (Methanal), Benzene, 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 characterized 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 (CO₂-Eq.). This means that the greenhouse potential of an emission is given in relation to CO₂. 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.

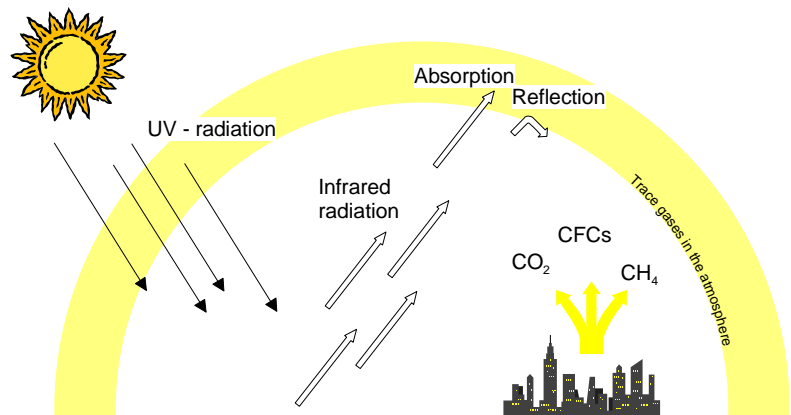


Figure A1: Greenhouse effect (KREISSIG 1999)

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 analyzing 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 ($\text{SO}_2\text{-Eq.}$). 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.

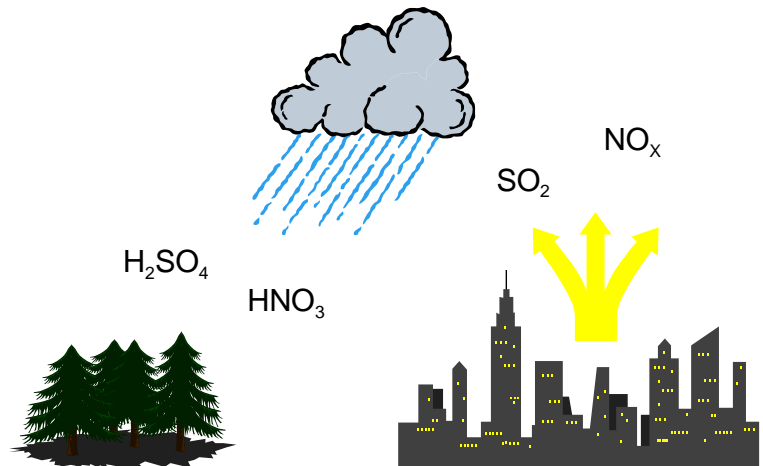


Figure A2: Acidification Potential (KREISSIG 1999)

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.

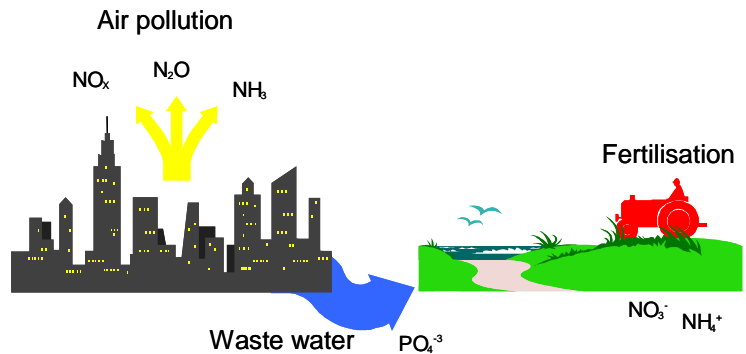


Figure A3: Eutrophication Potential (KREISSIG 1999)

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 existence of 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 (Figure A4).

In Life Cycle Assessments, photochemical ozone creation potential (POCP) is referred to in ethylene-equivalents (C₂H₄-Equiv.). 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.

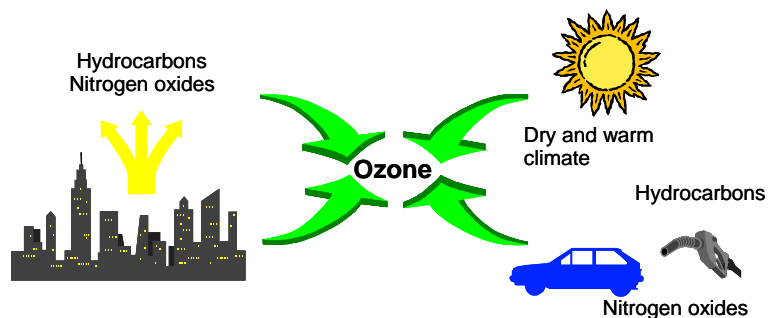


Figure A4: Photochemical Ozone Creation Potential

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

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
Resilient Linoleum Floor Covering

According to ISO 14025 and EN 15804

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.

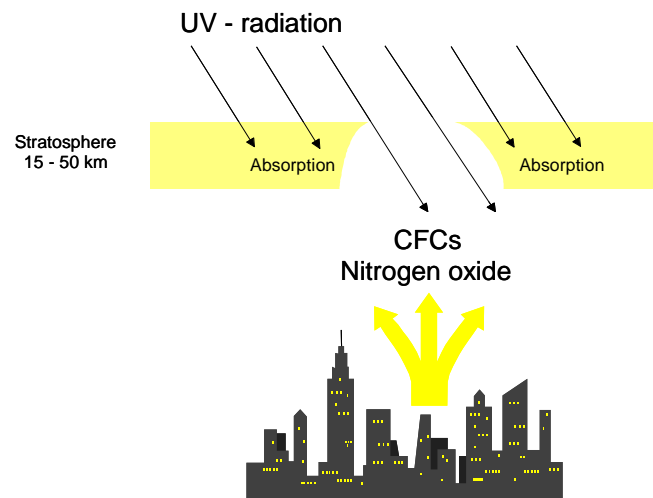


Figure A5:

Ozone Depletion Potential (KREISSIG 1999)

ENVIRONMENTAL PRODUCT DECLARATION



FLOORING SYSTEMS

Marmoleum Decibel
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