Environmental Product Declaration

ARMAFLEX® CLASS 0, ARMAFLEX® CLASS 1, ARMAFLEX® DS, ARMAFLEX ENDURA®, ARMAFLEX® AMP, ARMAFLEX® CLASS 0 PLUS & ARMAFLEX® FRV

ARMAFLEX® INSULATION FOR INDUSTRIAL AND BUILDING INSTALLATION

Armaflex®

Environmental protection is one of the main pillars of Armacell's corporate philosophy. It is an integral part of the business strategy and ranks equally with other company objectives.

Armacell practices active environmental protection throughout the company. To efficiently utilize resources, we are constantly searching for ways to reduce raw material use, energy consumption and waste.

In addition, Armacell makes considerable contribution to abating greenhouse-gas emissions.

Our aim is to gear all business activities towards protecting and conserving nature. The environmental policy oblige all Armacell employees worldwide to aim to protect the environment and conserve natural resources.

UL CERTIFIED
ENVIRONMENTAL PRODUCT DECLARATION
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ENVIRONMENTAL PRODUCT DECLARATION

Armaflex®

Armaflex® Class 0, Armaflex® Class 1, Armaflex® DS, Armaflex Endura®, Armaflex® AMP, Armaflex® Class 0 Plus & Armaflex® FRV

According to ISO 14025

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
DECLARATION HOLDER	Armacell
DECLARATION NUMBER	4786944121.101.1
DECLARED PRODUCT	Armaflex® Class 0, Armaflex® Class 1, Armaflex® DS, Armaflex Endura®, Armaflex® AMP, Armaflex® Class 0 Plus & Armaflex® FRV
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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:	Panel Review
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This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	
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Product definition

Company description

Armacell is a world leader in flexible insulation foams for the equipment insulation market and also a leading provider of engineered foams. In the year 2014, the company with currently 2,600 employees generated net sales of EUR 452.2 million.

With its 23 manufacturing plants in 16 countries on four continents, Armacell follows a strategy of internationalization. The company operates within two main businesses: the Advanced Insulation business develops flexible insulation foam products for the insulation of mechanical equipment. The Engineered Foams business develops and markets light foams for use in a broad range of end-markets.

The high-tech insulation products of Armacell increase the global energy efficiency and are used in many high-end facilities, including the Empire State Building and the International Space Station. They are an integral part of everyday life: beyond thermal insulation, Armacell products are used as acoustic insulation, as gaskets and seals in a variety of modern car models or as central components of wind turbine blades.

Product description

Armaflex® is a professional, closed-cell flexible elastomeric foam (FEF) insulation material used for continuous energy-saving and condensation control purposes. The combination of very low thermal conductivity and extremely high resistance to water vapour transmission prevents long-term energy losses and water vapour ingress and reduces the risk of corrosion under insulation. Armaflex® insulation is dust- and fibre-free, CFC- and HCFC-free with an ODP of zero.

- Armaflex® Class 0 is a flexible, closed-cell elastomeric nitrile rubber insulation that offers reliable protection against condensation and energy loss. It contains MICROBAN® antimicrobial protection to reduce mold and bacterial growth. This product meets Class 0 fire classification when tested to BS 476 Part 6 & 7 and is FM Approved product. Armaflex® Class 0 has achieved GREENGUARD Gold certification from the UL Environment as well as 2 Ticks (Very Good) in the Singapore Green Building Product rating from the Singapore Green Building Council (SGBC).
- Armaflex® Class 1 is a flexible, closed-cell elastomeric nitrile rubber insulation, that provides a highly efficient method of controlling condensation and insulating against both heat loss and heat gain. This product meets Class 1 fire classification when tested to BS 476 Part 7 and is FM Approved product. Armaflex® Class 1 has also achieved 1 Tick (Good) in the Singapore Green Building Product rating from the SGBC.
- Armaflex® DS is a unique insulation product with excellent fire safety performance. Specially developed to reliably meet B1 - Class B fire rating when tested to GB8624-2012. This product has achieved GREENGUARD Gold certification from the UL Environment and is also certified by the China Academy of Building Research as a Green

Building Product.

- Armaflex Endura® is a specially formulated closed-cell elastomeric insulation with aluminum foil facing. This product is certified as a "non-combustible material" when tested in accordance to Japan's Building Standard Law.
- Armaflex® AMP is an insulation product formulated to meet Class 0 fire classification when tested to BS 476 part 6 & 7 and meeting building code requirement when test to ASTM E84. It contains MICROBAN® antimicrobial protection to reduce mold and bacterial growth.
- Armaflex® Class 0 Plus is a flexible, closed-cell elastomeric nitrile rubber insulation that offers reliable protection against condensation and energy loss. It contains MICROBAN® antimicrobial protection to reduce mold and bacterial growth. This product meets Class 0 fire classification when tested to BS 476 Part 6 & 7.
- Armaflex® FRV is a flexible, fire-retardant foam insulation material tested in full-scale vertical pipe-chase tests. This high-performance product complies with the requirements for fire hazard properties of insulation materials per Specification C1.10 (Clause 7) of Australia's National Construction Code (NCC) Volume 1 and has Group Number Classification 1 according to New Zealand Building Code Verification Method C/VM2, Appendix A. This product is also tested to NFPA 274 of the National Fire Protection Association. Armaflex® FRV has been verified as meeting Ecospecifier Verified Product Standard and is likely to contribute to the achievement of Green Star® credits

Table 1: Composition/formulation of the seven Armaflex® insulation products

Parameter	Unit	Armaflex® Class 0	Armaflex® Class 1	Armaflex® DS	Armaflex Endura®	Armaflex® AMP	Armaflex® Class 0 Plus	Armaflex® FRV
Gross density	kg/m3	44	42	45	60	60	44	57
Water vapor diffusion resistance factor	-	≥10,000	≥10,000	≥10,000	≥5,000	≥ 5,000	≥10,000	≥5,000
Thermal conductivity @ 0°C	W/(m.K)	0.034	0.034	0.034	0.039	0.039	0.033	0.034
Maximum service temperature	°C	105 (tube) 85 (sheet)	105 (tube) 85 (sheet)	105 (tube) 85 (sheet)	85 (sheet)	85 (sheet)	85 (sheet)	105 (tube) 85 (sheet)
Minimum service temperature	°C	-50	-50	-50	-50	-50	7	-50
Fire resistance rating		Class 0 per BS 476 part 6&7 FM Approved	Class 1 per BS 476 part 7 FM Approved	Class B1 per GB 8624	Classifies as 'non-combustible material" under Japan's Building Standard Law when tested to ISO 5660	Class 0 per BS 476 part 6&7 Meet building code requirement when tested to ASTM E84	Class 0 per BS 476 part 6 & 7	Comply to NCC Vol. 1 requirement for fire hazard properties per Spec C1.10 (Clause 7) Group 1 per NZBC

Armaflex®

Armaflex® Class 0, Armaflex® Class 1, Armaflex® DS, Armaflex Endura®,
Armaflex® AMP, Armaflex® Class 0 Plus & Armaflex® FRV

According to ISO 14025

Manufacturing locations

This Environmental Product Declaration (EPD) represents the production of Armaflex® Class 0, Armaflex® Class 1, Armaflex® DS, Armaflex Endura®, Armaflex® AMP, Armaflex® Class 0 Plus, Armaflex® FRV pipe and sheet insulation at Armacell's production facilities in Panyu (CHN), Suzhou (CN), Cheonan (KOR), Pune (IND) and Dandenong (AUS).

Application and use

Armaflex® insulation materials are used to insulate pipes, air ducts and vessels including fittings and flanges of industrial installations and building equipment. The functions of Armaflex® insulation materials are as follows:

- Energy conservation, noise- and condensation-control in refrigeration and air conditioning equipment and process plants.
- Energy conservation according to local energy-saving laws, reduction of heat loss and noise in heating and plumbing systems.
- Condensation control and noise reduction in service-water and waste-water systems.
- Condensation control, energy-conservation and noise control in refrigeration and air conditioning equipment in the ship-building sector.

Insulation materials based on synthetic rubber do not absorb moisture from the air. Hence, normal-occurring building moisture which has insignificant effects on thermal conductivity would not affect the long-term performance of the material.

Installation

The product is installed by using knives to cut according to desired length and size and joined using adhesive. No special tools or protection is necessary. The recommended installation method depends on the product and system as described in the respective documents (e.g. application manuals) and on the data sheets. More details can be found on www.armacell.com.

Health, Safety, and Environment Aspects during Installation

Armaflex® Class 0, Armaflex® Class 1, Armaflex® DS, Armaflex® Class 0 Plus and Armaflex® FRV are nitrile butadiene rubber foams while Armaflex Endura® and Armaflex® AMP are manufactured with Armaprene – a patented technology. These products contain flame-retardant additives.

When handling and installing insulation material, one should practice reasonable care as a normal safety precaution. When applying adhesives, the information given in the relevant safety data sheets is to be heeded.

Toxicological information: After contact with skin or eyes, no special measures are required. No hazards in terms of normal handling and skin contact.

Ecological information: Environmentally harmless:

· Insoluble in water: no contamination

Production Content

Material Content

There are seven Armaflex® insulation products in this EPD, namely Armaflex® Class 0, Armaflex® Class 1, Armaflex® DS, Armaflex Endura®, Armaflex® AMP, Armaflex® Class 0 Plus and Armaflex® FRV. These FEF-insulation materials are based on synthetic rubber, consisting of approximately 20 basic components. The following table displays the composition split into functional substance groups.

Table 2: Composition/formulation of the seven Armaflex® insulation products

	Armaflex® Class 0	Armaflex® Class 1	Armaflex® DS	Armaflex Endura®	Armaflex® AMP	Armaflex® Class 0 Plus	Armaflex® FRV
Rubber and Polymers	25%	28%	28%	20%	20%	25%	26%
Fillers and pigments	4%	7%	3%	4%	4%	4%	17%
Blowing agent	13%	15%	14%	9%	9%	13%	12%
Vulcanization System, additives, plasticizers	26%	26%	22%	24%	24%	26%	26%
Flame retardant	32%	25%	33%	43%	43%	32%	19%

Manufacturing Process

Armaflex® Class 0, Armaflex® Class 1, Armaflex® DS, Armaflex Endura®, Armaflex® AMP, Armaflex® Class 0 Plus and Armaflex® FRV share similar manufacturing processes and life cycle stages, with the key difference on performance related to fire resistance. Armaflex® products are manufactured in a pressure-less, continuous and discontinuous production process. In the first step, a homogenous compound is produced with rubber, additives, ancillary materials, blowing and vulcanization agents. This is done on the rolling mill or in the internal mixer flowed by the rolling mill. Rubber extruders are used to process the compounds to produce raw profiles with defined dimensions. Here exact compliance with the dimensions for the raw profile is crucial for the dimensional accuracy of the foamed product.

In the case of discontinuous, pressure-less production process, the raw profiles are cut to length and then foamed in a hot-air oven. In the case of the continuous, pressure-less process, the extruded profile is fed directly onto a vulcanization line whose energy source may be hot air, for example. In foam production, vulcanization and blowing process run alongside each other. Both reactions are regulated by temperature control. Recipe and temperature control determine the properties of the foam.

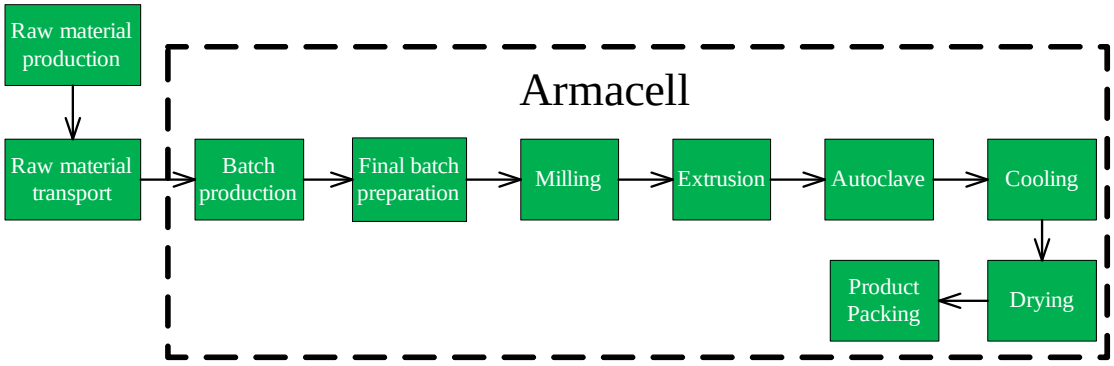

Figure 1: Manufacturing process for seven Armaflex® insulation products

Health, Safety, and Environmental Aspects during Production

Production at Armacell adheres to the according national guidelines and regulations during all manufacturing steps, and in all facilities. Certification of the environmental management system is in accordance with ISO 14001.

Life Cycle Assessment-Product System and Modelling

A 'cradle-to-grave' life cycle assessment (LCA) was conducted on seven Armaflex® products (Armaflex® Class 0, Armaflex® Class 1, Armaflex® DS, Armaflex Endura®, Armaflex® AMP, Armaflex® Class 0 Plus and Armaflex® FRV). The study was conducted according to the requirements of the Product Category Rules (PCR) for Building Envelope Thermal Insulation (version 1.3, June 1 2014. Product Category Rule Number 000001) and conforms to ISO 14040/14044 standards. The background LCA was verified for conformance to the PCR and ISO standards. EPDs of Mechanical Insulation may not be compared if they do not comply with the same Product Category Rules or if they are from different programs.

PCR help to increase comparability of products but one must take into consideration that EPDs, even when they comply with same PCR, can still differ due to differences in system boundaries, background data used and other variables.

Function Unit

The Product Category Rule defines the declared unit for this analysis as "1 kg of insulation material plus 1 m^2 facing with a building service life of 60 years". In this analysis none of the products have facing material. A declared unit of "1 kg of insulation material without facing with a building service life of 60 years" is used.

Life Cycle Stages Assessment

The LCA was conducted for cradle-to-grave, from extraction of raw materials from nature to the final disposal of the product. These system boundaries cover the following stages:

Raw material acquisition: Raw material extraction and production, raw material transportation from supplier to Armaflex® production sites;

Manufacturing: Manufacturing of masterbatch (in Panyu), transportation of auxiliary supplies, manufacturing of insulation, finished product packaging;

Transportation: Distribution of product from the production site to the building site (including transportation to distributor if applicable), transportation of masterbatch from Panyu to other plants in Asia Pacific;

Installation: Installation of product;

End-of-Life: Transportation to final disposition site, product disposition.

System boundaries

This study of Armaflex® foam insulation products (Armaflex® Class 0, Armaflex® Class 1, Armaflex® DS, Armaflex Endura®, Armaflex® AMP, Armaflex® Class 0 Plus and Armaflex® FRV) includes life cycle information from cradle-to-grave. This analysis includes the consideration of the product stage for foam insulation tubes and sheets (extraction and processing of raw materials, transportation to the factory and manufacturing processes with packaging). The construction process stage covers insulation product transportation to the building site from the factory gate and the installation phase. Lastly, the end-of-life stage includes transportation to final disposition site and disposal. Resources of energy and materials used together with emissions to soil, water and air created over all life cycle stages of products are accounted for in the calculations of the Impact Assessment. Building operational energy and water use are considered outside of this study's scope: any impact that the use of insulation may have on a building's energy consumption is not calculated or incorporated into the analysis.

Figure 2: System boundaries

Assumptions

Manufacturing:

- As the production process of masterbatch is basically same, the input and output of masterbatch production processes of different products are considered the same (except for raw materials);
- The process of foaming product manufacturing is considered representative from Panyu site and will not be subjected to significant influence by variation of production location. Thus the foaming process from different factories used the same input and output data from Panyu site for modeling. The data of Armaflex® Class 1, Armaflex® Class 0 and Armaflex® DS are all derived from Panyu factory.
- Armaflex® AMP and Armaflex Endura® will be made in Panyu factory. Production data for these two products is substituted by the average data from existing production line.
- In the production process, the flow of material for generating the scraps recycled for making other sound proof products is not considered in the life cycle modeling. However, the additional energy consumption, water consumption and emissions from scrap generation are considered.
- Material flow of trace scrap which is evaporated during product is included in the system boundary.
- The transportation distance of packaging and auxiliary materials, like lubricating oil and engine oil is assumed to be 30 km as more accurate data is unavailable.

Transportation:

- Distance of product transportation including land transportation and oversea transportation uses estimated figure.

Installation:

- Armaflex® products do not require replacements over the duration of building reference service life.
- Installation and dismantling is done by hand and assumed not to contribute to environmental impact.
- Installation assume generate 1% scrap and scrap applies the same end-of-life disposal scenario as the dismantled product at end-of-life.
- Consumption of adhesive used for product installation is based on assumption of types and quantity.

End-of-Life:
Disposal scenario is simplified in this study. We adopted the municipal waste disposal scenario, where waste-to-energy is not considered in this modeling and the distance from the construction site to the incineration site is assumed to be 50 km.

Cut-off Criteria

Processes or activities that contribute no more than 2% of the total mass and 1% of the total energy may be omitted under the PCR cut-off criteria. If the omitted material flows have relevant contributions to the selected impact categories, their exclusion must be justified by a sensitivity analysis. The sum of the excluded material flows must not exceed 5% of mass, energy or environmental relevance.

It is estimated that the largest omitted mass flow in the product life cycle is associated with installation, but it does not exceed 2% of total mass flow in the worst-case scenario. It is estimated that the environmental relevance over the impacted categories during the whole product life cycle does not exceed 2% in the worst-case scenario.

The cut-off criteria were applied to the capital equipment production and maintenance. It was assumed that the impact associated with these aspects were sufficiently small enough to fall below the cut-off when it is scaled down to the declared unit.

Transportation

The transportation stage includes the transportation of the masterbatch and foaming products. The transportation of raw material and auxiliary supplies are considered in the stage of “raw material acquisition” and “manufacturing”. At the end-of-life stage, the transportation of waste production from the construction site to the incineration plant is also reported.

The transportation of the masterbatch is weighted average by annual production. The transportation of foaming products includes two parts, from plant to warehouse and from warehouse to construction site.

Period under consideration

The data collection refers to the yearly production in 2014.

Background Data

SimaPro 8 software was used to create the LCA model. Ecoinvent 3 with China regionalization data and the ELCD database were used to obtain LCI secondary data and average data for upstream (raw material production) and downstream (installation and end-of-life) processes.

Data Quality

The foreground data collected by the manufacturer is based on the yearly production amount and extrapolation of measurements on specific machines and plants. The data covers all important process steps and technologies over the supply chain of Armaflex® foam insulation products (Armaflex® Class 0, Armaflex® Class 1, Armaflex® DS, Armaflex Endura®, Armaflex® AMP, Armaflex® Class 0 Plus and Armaflex® FRV).The large majority of secondary data is from SimaPro 8 databases and thus represent reproducible, critically reviewed data. Consistency is applied wherever possible. The data used is complete and reproducible to limit uncertainty. The geographical region represented is Asia, including China, Australia, South Korea, India and Vietnam.

If data was found missing, it was critically analyzed and if it had a significant impact on model results, the analysis was revised in SimaPro. Datasets for missing data were gathered and prepared based on a literature study.

Allocation

Allocation refers to partitioning of input or output flows of a process or a product system between the product systems under study and one or more other product systems.

Input: The consumption of raw materials is allocated by mass ratio. The transportation of raw materials is allocated by mass. For masterbatch production, the total consumption of energy and water during manufacturing is equally allocated to per unit mass of masterbatch. The allocation of total energy consumption among various productions stages is divided by calculation of power consumption rate times operation time of each product stage for each product type during production, as no other record of allocation of energy consumption for each type of product is available.

Output: The environmental emissions of masterbatch and forming product are both allocated by mass to each unit product.

Use

In the use stage, foam insulation tubes do not require maintenance or replacement and they do not require energy or material inputs. Analyzed products do not create emissions to air or discharges to water or soil. It is assumed that tube and sheet insulation have a service life of 60 years, equal to that of the building.

End of life

According to Armacell, products are consumed mainly in about 15 countries. For the simplicity of the study, we assume that all used products are incinerated. The disposal of the used product will adopt a country or region average incineration process for municipal waste treatment. In the disposal scenario, the transportation of waste products is assumed – the distance from construction site to the incineration plant is set to be 50km by lorry.

Life Cycle Assessment Results and Analysis

Use of material and Energy Resources

Use of Material and Energy Resources in Table 3 displays the material and energy demand for the declared unit of products over their life cycle from cradle to grave. The results cover:

- Raw materials + Masterbatch transportation and production – manufacturing and acquisition of raw materials for declared unit, transportation of masterbatch, masterbatch production.
- Manufacturing– production of foaming productions plus packaging for declared unit

- Transport– foaming products transportation from plants to warehouse, foaming products transportation from warehouse to construction site plants.
- Installation – installation of the declared unit using adhesive;
- End-of-life stage – transportation of the declared unit, adhesive and packaging to the final disposal site 50 km away and the disposal of product waste as incineration.

Table 3: Material and Energy Resources Demand (by type)

Impact category	Unit	Armaflex® Class 0	Armaflex® Class 1	Armaflex® DS	Armaflex Endura®	Armaflex® AMP	Armaflex® Class 0 Plus	Armaflex® FRV
Use of non-renewable material resources	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of renewable material resources	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable, fossil	MJ	7.22E+01	7.16E+01	7.52E+01	6.81E+01	6.21E+01	7.69E+01	6.27E+01
Non-renewable, biomass	MJ	8.06E-03	8.10E-03	8.10E-03	8.69E-03	8.16E-03	8.10E-03	8.17E-03
Non-renewable, nuclear	MJ	6.26E-02	7.50E-02	8.79E-02	4.62E-02	3.97E-02	4.32E-02	3.96E-02
Renewable, biomass	MJ	2.25E+00	2.21E+00	2.21E+00	2.30E+00	2.55E+00	2.33E+00	2.21E+00
Renewable, water	MJ	1.50E+00	1.58E+00	1.86E+00	1.32E+00	9.29E-01	8.93E-01	7.82E-01
Renewable, wind, solar, geothermal	MJ	1.03E-01	7.23E-02	7.04E-02	1.32E-01	7.05E-02	1.44E-01	7.30E-02

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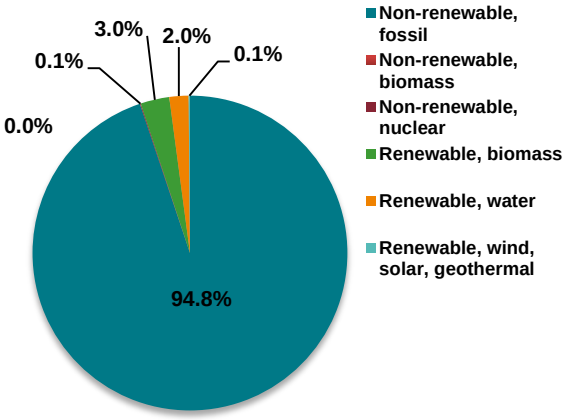
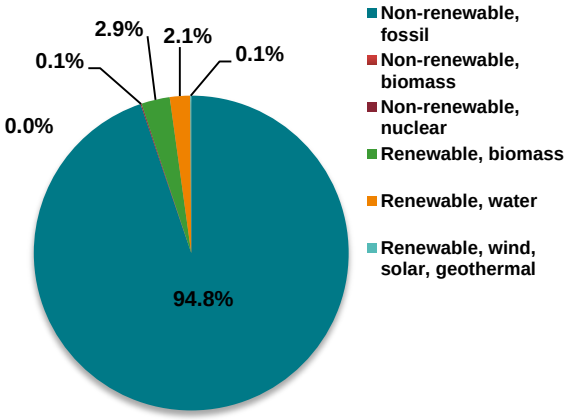
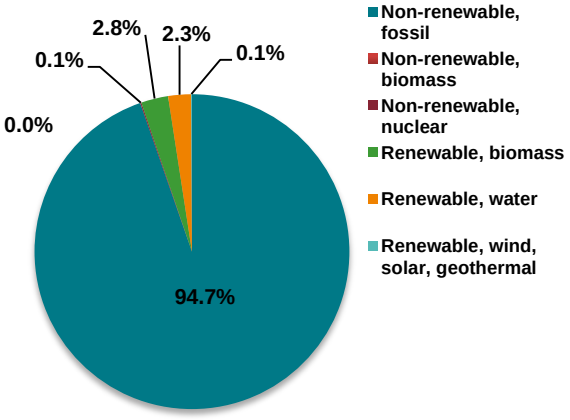
Armaflex® Class 0



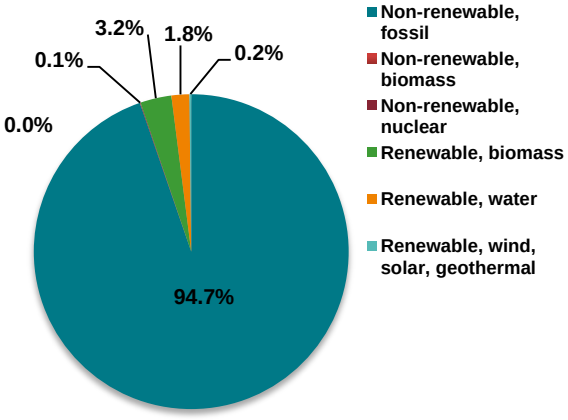
Armaflex® Class 1



Armaflex® DS



Armaflex Endura®



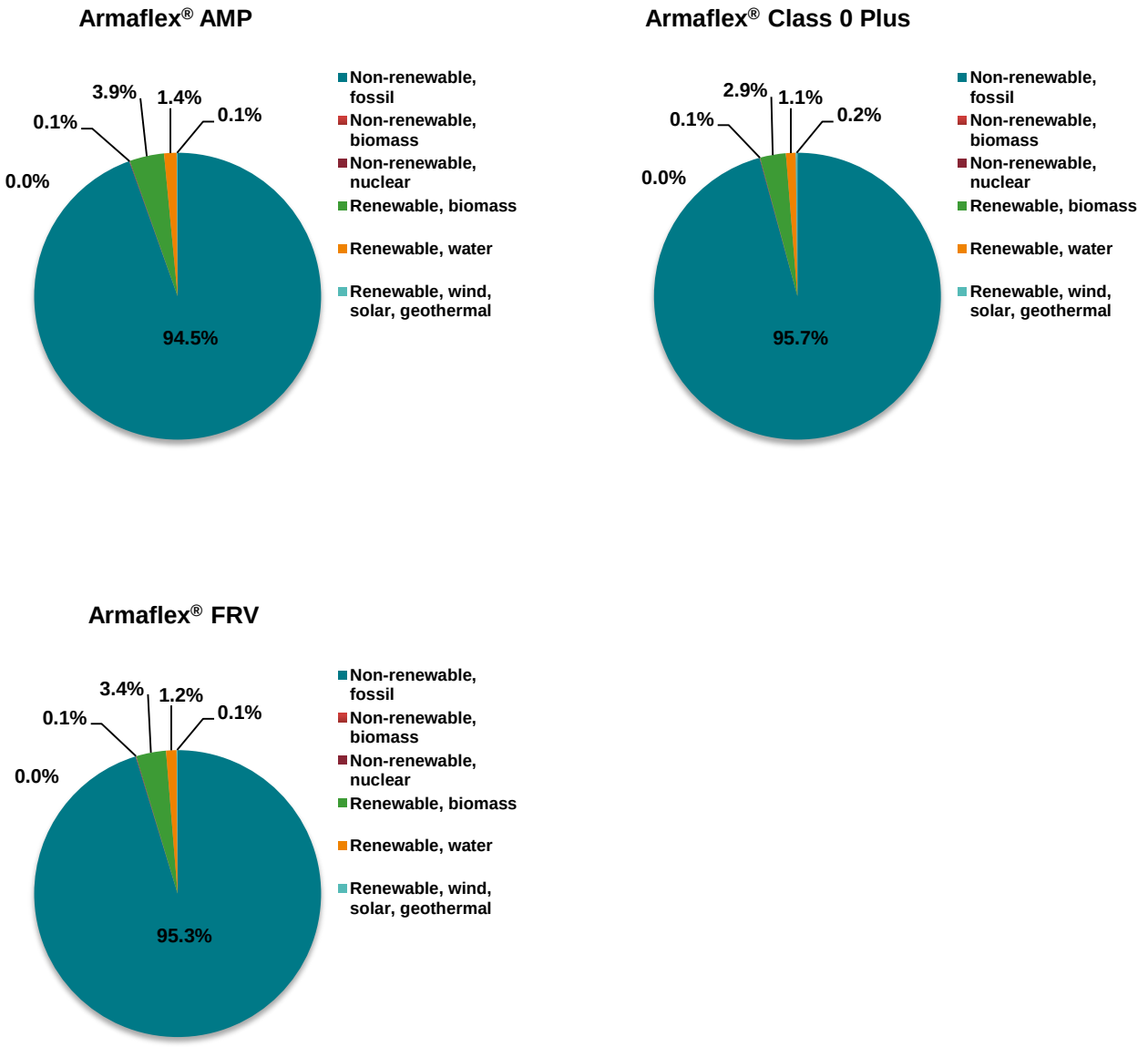


Figure 3: Cumulative energy demand by product declared unit

Life cycle Impact Assessment

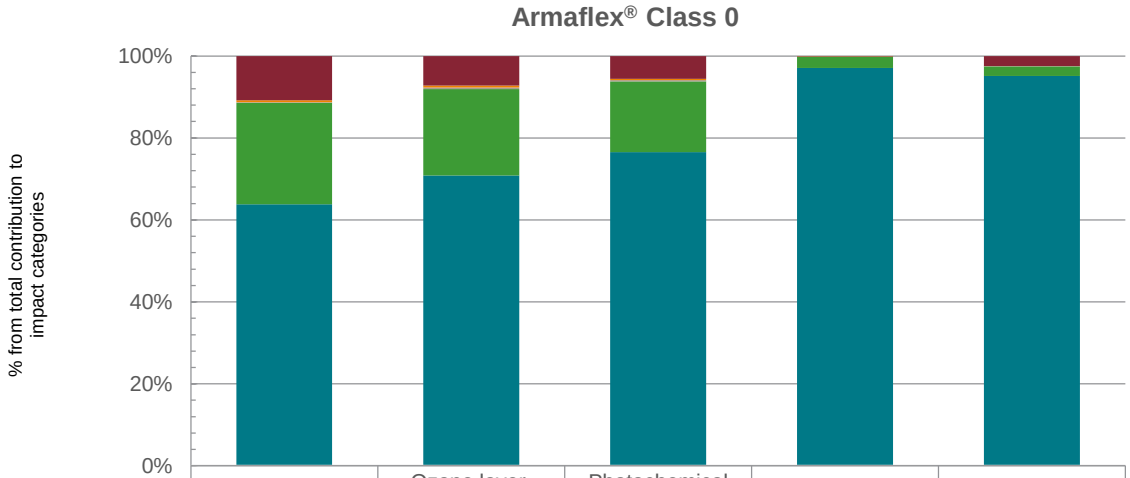
Based on the model of 7 insulation products, the CML IA (baseline) result is calculated and Table 4 shows the results. The results cover:

- Raw materials+ Masterbatch transportation and production – manufacturing and acquisition of raw materials for declared unit, transportation of masterbatch, masterbatch production.

- Manufacturing– production of foaming productions plus packaging for declared unit.
- Transport– foaming products transportation from plants to warehouse, foaming products transportation from warehouse to construction site plants.
- Installation – installation of the declared unit using adhesive;
- End of life stage – transportation of the declared unit, adhesive and packaging to the final disposal site 50 km and the disposal of product waste as landfill.

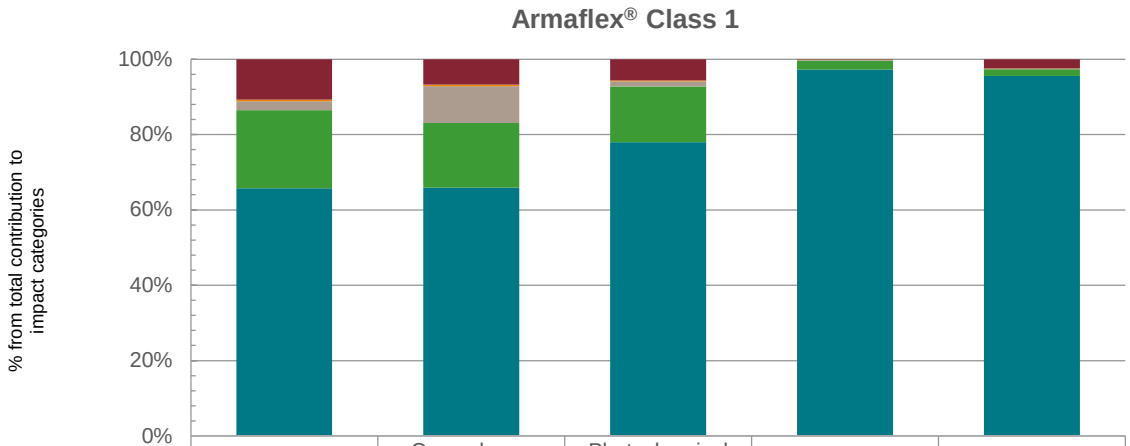
Table 4: Life cycle Impact results per declared unit

Impact category	Unit	Armaflex® Class 0	Armaflex® Class 1	Armaflex® DS	Armaflex Endura®	Armaflex® AMP	Armaflex® Class 0 Plus	Armaflex® FRV
Global warming (GWP100a)	kg CO_2 eq	5.64E+00	5.69E+00	5.91E+00	4.60E+00	4.60E+00	5.91E+00	5.53E+00
Ozone layer depletion (ODP)	kg CFC-11 eq	2.30E-07	2.47E-07	2.56E-07	2.12E-07	2.12E-07	2.41E-07	2.20E-07
Photochemical oxidation	kg C_2H_4 eq	2.35E-03	2.34E-03	2.42E-03	1.83E-03	1.83E-03	2.49E-03	2.24E-03
Acidification	kg SO_2 eq	3.73E-01	3.80E-01	3.96E-01	2.63E-01	2.63E-01	3.76E-01	3.33E-01
Eutrophication	kg PO_4--- eq	9.40E-02	9.53E-02	9.91E-02	6.62E-02	6.62E-02	9.49E-02	8.92E-02



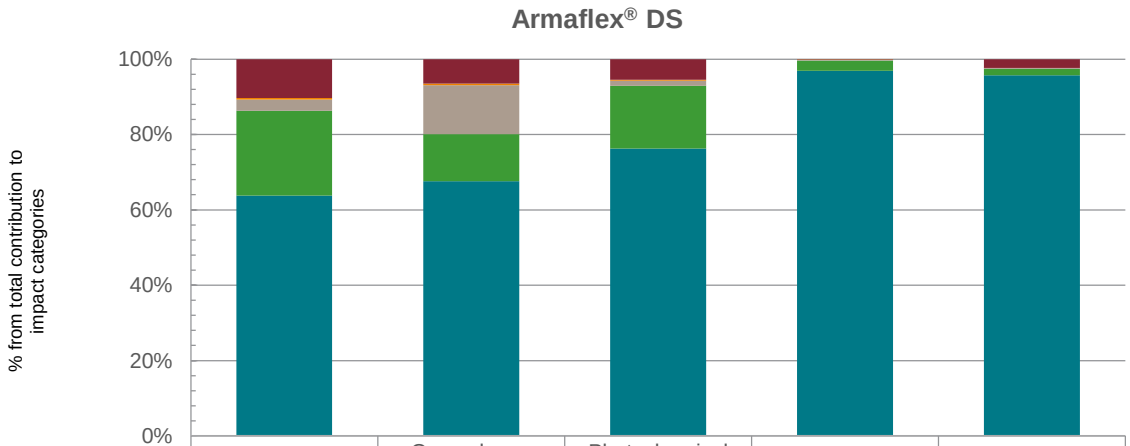
	Global warming	Ozone layer depletion	Photochemical oxidation	Acidification	Eutrophication
End of life	10.82%	7.22%	5.61%	0.15%	2.47%
Installation	0.49%	0.48%	0.28%	0.03%	0.02%
Transportation	0.16%	0.40%	0.30%	0.04%	0.02%
Manufacturing	24.74%	21.04%	17.30%	2.73%	2.39%
Raw_material_MBtrans_Mbproduction	63.80%	70.86%	76.51%	97.06%	95.10%

Figure 4: Life cycle impact results of Armaflex® Class 0 over life stages



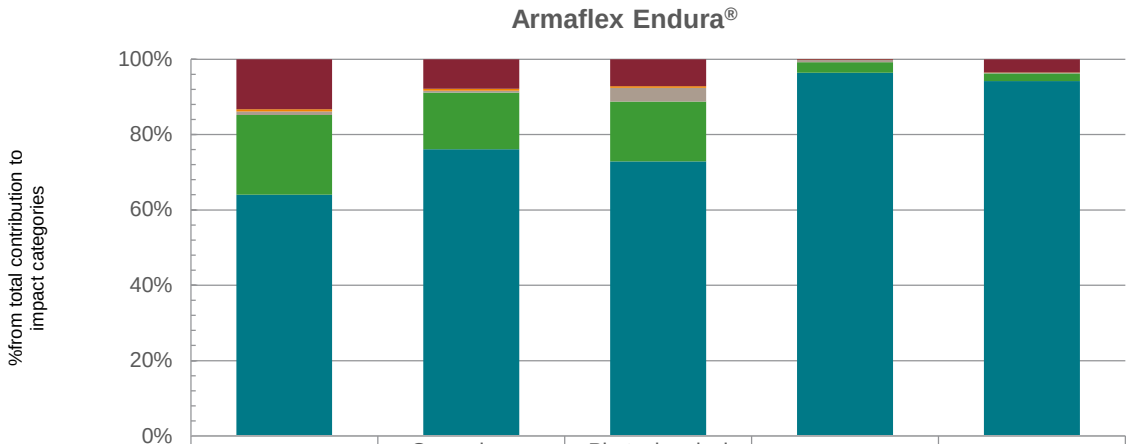
	Global warming	Ozone layer depletion	Photochemical oxidation	Acidification	Eutrophication
End of life	10.72%	6.71%	5.63%	0.14%	2.43%
Installation	0.48%	0.45%	0.28%	0.03%	0.02%
Transportation	2.31%	9.75%	1.34%	0.22%	0.19%
Manufacturing	20.74%	17.18%	14.75%	2.33%	1.86%
Raw_material_MBtrans_Mbproduction	65.74%	65.90%	78.00%	97.28%	95.50%

Figure 5: Life cycle impact results of Armaflex® Class 1 over life stages



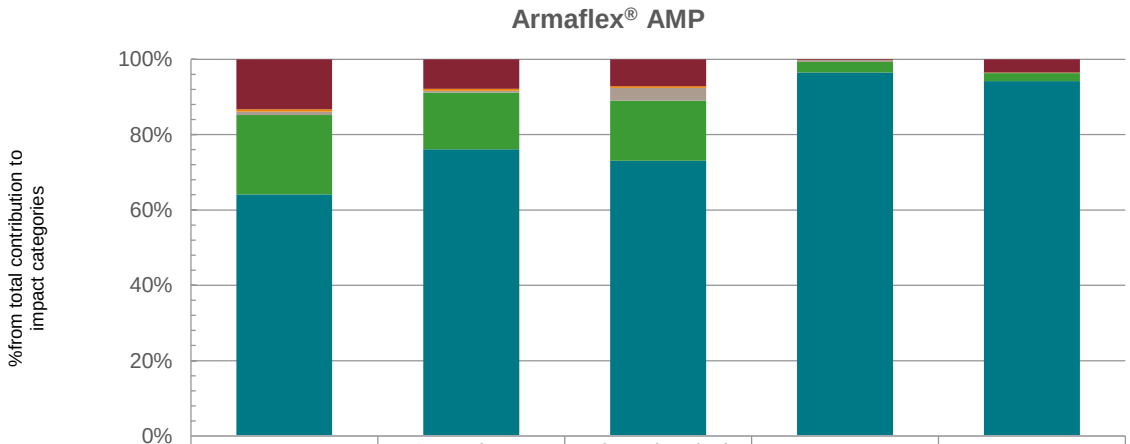
	Global warming	Ozone layer depletion	Photochemical oxidation	Acidification	Eutrophication
End of life	10.31%	6.48%	5.45%	0.14%	2.35%
Installation	0.46%	0.43%	0.27%	0.03%	0.02%
Transportation	2.97%	13.01%	1.38%	0.24%	0.23%
Manufacturing	22.47%	12.50%	16.60%	2.69%	1.66%
Raw_material_MBtrans_Mbproduction	63.79%	67.57%	76.30%	96.91%	95.74%

Figure 6: Life cycle impact results of Armaflex® DS over life stages



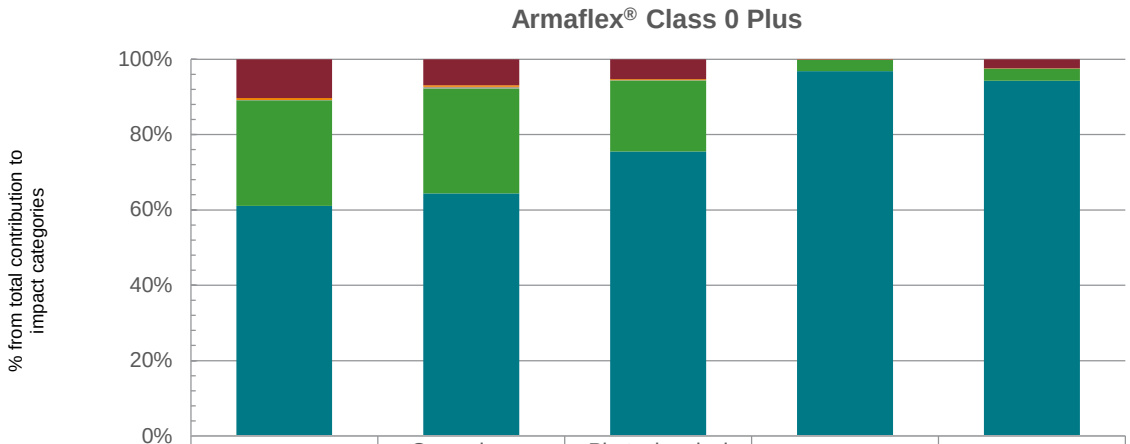
	Global warming	Ozone layer depletion	Photochemical oxidation	Acidification	Eutrophication
End of life	13.25%	7.85%	7.20%	0.21%	3.51%
Installation	0.60%	0.52%	0.36%	0.04%	0.03%
Transportation	1.00%	0.47%	3.65%	0.52%	0.20%
Manufacturing	21.09%	15.08%	15.89%	2.81%	2.06%
Raw_material_MBtrans_Mbproduction	64.07%	76.09%	72.90%	96.43%	94.20%

Figure 7: Life cycle impact results of Armaflex Endura® over life stages



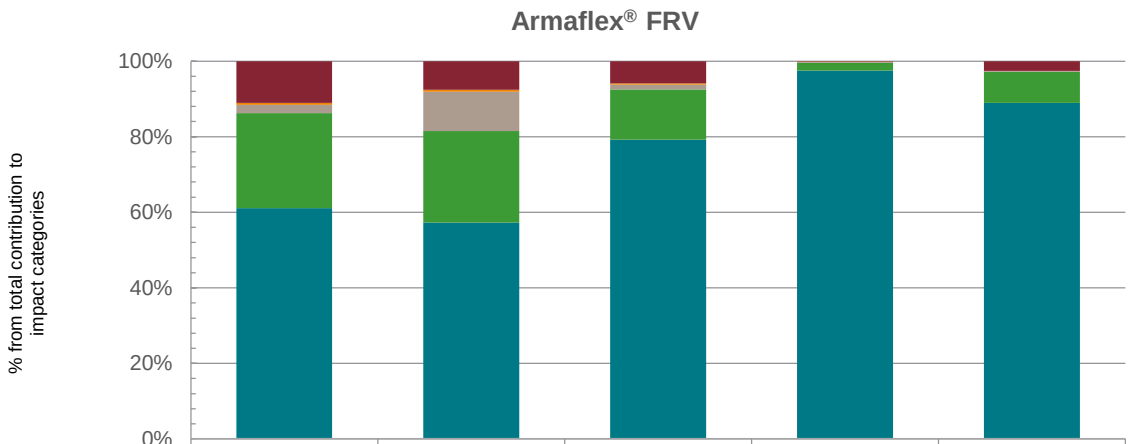
	Global warming	Ozone layer depletion	Photochemical oxidation	Acidification	Eutrophication
End of life	13.26%	7.85%	7.22%	0.21%	3.51%
Installation	0.60%	0.52%	0.36%	0.04%	0.03%
Transportation	0.95%	0.46%	3.46%	0.49%	0.19%
Manufacturing	21.10%	15.08%	15.92%	2.81%	2.06%
Raw_material_MBtrans_Mbproduction	64.10%	76.09%	73.04%	96.46%	94.21%

Figure 8: Life cycle impact results of Armaflex® AMP over life stages



	Global warming	Ozone layer depletion	Photochemical oxidation	Acidification	Eutrophication
End of life	10.33%	6.89%	5.30%	0.15%	2.44%
Installation	0.47%	0.46%	0.26%	0.03%	0.02%
Transportation	0.09%	0.38%	0.04%	0.01%	0.01%
Manufacturing	28.06%	27.90%	18.88%	3.01%	3.22%
Raw_material_MBtrans_Mbproduction	61.06%	64.36%	75.51%	96.82%	94.30%

Figure 9: Life cycle impact results of Armaflex® Class 0 Plus over life stages



	Global warming	Ozone layer depletion	Photochemical oxidation	Acidification	Eutrophication
End of life	11.03%	7.55%	5.90%	0.16%	2.60%
Installation	0.50%	0.50%	0.29%	0.03%	0.02%
Transportation	2.25%	10.42%	1.31%	0.23%	0.19%
Manufacturing	25.13%	24.23%	13.29%	2.09%	8.20%
Raw_material_MBtrans_Mbproduction	61.09%	57.29%	79.20%	97.49%	88.99%

Figure 10: Life cycle impact results of Armaflex® FRV over life stages

Waste to Disposal

There is hazardous waste associated with the production of the masterbatch and the foaming products of all 7 types of Armaflex® insulation materials. Installation waste is assumed to be 1% of products.

Table 5: Waste estimation for product declared unit from cradle-to-grave

Impact category	Unit	Armaflex® Class 0	Armaflex® Class 1	Armaflex® DS	Armaflex Endura®	Armaflex® AMP	Armaflex® Class 0 Plus	Armaflex® FRV
Hazardous waste	kg	2.91E-01	3.58E-01	3.91E-01	1.48E-01	1.48E-01	2.29E-01	2.08E-01
Non-hazardous waste	kg	2.78E-02	4.18E-02	5.23E-02	5.01E-06	4.89E-06	5.56E-06	5.39E-06
Radioactive waste	kg	2.64E-10	3.50E-10	4.20E-10	1.22E-10	1.22E-10	1.50E-10	1.43E-10

Scaling to Various Pipe Sizes and Sheet thickness

In this report, a declared unit is used instead of the functional unit due to difficulties in defining a single, generic functional unit that is representative of all pipe insulation and sheet insulation ranges. Calculated impact results above can be multiplied by scaling factors to estimate environmental impact per one meter of insulation for pipe and one square meter for sheet.

Scaling factors for all 7 types of Armaflex® foam insulation tubes are displayed in Tables 6 – 10.

For pipe,

Formula: Scaling factor=Pi*(ID+WT)*WT*Density

Where, Pi=3.14; ID=ID insulation; WT=wall thickness.

For sheet,

Formula: Scaling factor=WT*Density

Where WT=wall thickness

Table 6: Scaling factor to one meter of Armaflex® Class 0

Copper pipe size (in)	Steel Pipe, DN	ID Insulation (mm)	Wall Thickness (mm)							
			6	9	13	19	25	32	40	50
1/4		6	0.0100	0.0187	0.0341	0.0657	0.1071	0.1681	0.2543	0.3870
3/8	6	10	0.0133	0.0236	0.0413	0.0762	0.1210	0.1858	0.2765	0.4147
1/2		12	0.0149	0.0261	0.0449	0.0814	0.1279	0.1946	0.2875	0.4285
5/8	8	15	0.0174	0.0299	0.0503	0.0893	0.1382	0.2079	0.3041	0.4492
3/4		20	0.0216	0.0361	0.0593	0.1024	0.1555	0.2300	0.3318	0.4838
7/8	15	22	0.0232	0.0386	0.0629	0.1077	0.1624	0.2389	0.3428	0.4976

1		25	0.0257	0.0423	0.0683	0.1156	0.1728	0.2521	0.3594	0.5184
1 1/8	20	28	0.0282	0.0460	0.0737	0.1234	0.1832	0.2654	0.3760	0.5391
1 1/4		32	0.0315	0.0510	0.0809	0.1339	0.1970	0.2831	0.3981	0.5667
1 3/8	25	35	0.0340	0.0547	0.0863	0.1418	0.2073	0.2964	0.4147	0.5875
1 1/2		38	0.0365	0.0585	0.0916	0.1497	0.2177	0.3096	0.4313	0.6082
1 5/8	32	42	0.0398	0.0634	0.0988	0.1602	0.2315	0.3273	0.4534	0.6359
1 7/8	40	48	0.0448	0.0709	0.1096	0.1760	0.2523	0.3539	0.4866	0.6773
2 1/8		54	0.0498	0.0784	0.1204	0.1917	0.2730	0.3804	0.5197	0.7188
2 3/8	50	60	0.0547	0.0858	0.1312	0.2075	0.2937	0.4069	0.5529	0.7603
2 5/8		67	0.0605	0.0945	0.1438	0.2259	0.3179	0.4379	0.5916	0.8086
3	65	76	0.0680	0.1057	0.1599	0.2495	0.3490	0.4777	0.6414	0.8708
3 1/8		80	0.0713	0.1107	0.1671	0.2600	0.3629	0.4954	0.6635	0.8985
3 1/2	80	89	0.0788	0.1219	0.1833	0.2836	0.3940	0.5352	0.7133	0.9607
	90	102	0.0896	0.1381	0.2067	0.3178	0.4389	0.5927	0.7851	1.0505
4 1/4		108	0.0945	0.1456	0.2174	0.3335	0.4596	0.6193	0.8183	1.0920
	100	114	0.0995	0.1530	0.2282	0.3493	0.4803	0.6458	0.8515	1.1335
	125	140	0.1211	0.1854	0.2749	0.4176	0.5702	0.7608	0.9953	1.3132
	150	168	0.1443	0.2202	0.3253	0.4911	0.6670	0.8847	1.1501	1.5067

Table 7: Scaling factor to one meter of Armaflex® Class 1

Copper pipe size (in)	Steel Pipe, DN	ID Insulation (mm)	Wall Thickness (mm)							
			6	9	13	19	25	32	40	50
1/4		6	0.0095	0.0178	0.0326	0.0627	0.1023	0.1604	0.2428	0.3695
3/8	6	10	0.0127	0.0226	0.0395	0.0727	0.1155	0.1773	0.2639	0.3958
1/2		12	0.0143	0.0249	0.0429	0.0777	0.1221	0.1858	0.2744	0.4090
5/8	8	15	0.0166	0.0285	0.0480	0.0852	0.1319	0.1984	0.2903	0.4288
3/4		20	0.0206	0.0344	0.0566	0.0978	0.1484	0.2196	0.3167	0.4618
7/8	15	22	0.0222	0.0368	0.0600	0.1028	0.1550	0.2280	0.3272	0.4750
1		25	0.0245	0.0404	0.0652	0.1103	0.1649	0.2407	0.3431	0.4948
1 1/8	20	28	0.0269	0.0439	0.0703	0.1178	0.1748	0.2533	0.3589	0.5146
1 1/4		32	0.0301	0.0487	0.0772	0.1279	0.1880	0.2702	0.3800	0.5410
1 3/8	25	35	0.0325	0.0523	0.0823	0.1354	0.1979	0.2829	0.3958	0.5608

1 1/2		38	0.0348	0.0558	0.0875	0.1429	0.2078	0.2956	0.4117	0.5806
1 5/8	32	42	0.0380	0.0606	0.0943	0.1529	0.2210	0.3125	0.4328	0.6070
1 7/8	40	48	0.0428	0.0677	0.1046	0.1680	0.2408	0.3378	0.4645	0.6465
2 1/8		54	0.0475	0.0748	0.1149	0.1830	0.2606	0.3631	0.4961	0.6861
2 3/8	50	60	0.0523	0.0819	0.1252	0.1981	0.2804	0.3885	0.5278	0.7257
2 5/8		67	0.0578	0.0903	0.1372	0.2156	0.3035	0.4180	0.5647	0.7719
3	65	76	0.0649	0.1009	0.1527	0.2382	0.3332	0.4560	0.6122	0.8313
3 1/8		80	0.0681	0.1057	0.1595	0.2482	0.3464	0.4729	0.6333	0.8577
3 1/2	80	89	0.0752	0.1164	0.1750	0.2708	0.3760	0.5109	0.6808	0.9170
	90	102	0.0855	0.1318	0.1973	0.3033	0.4189	0.5658	0.7495	1.0028
4 1/4		108	0.0903	0.1389	0.2076	0.3184	0.4387	0.5911	0.7811	1.0424
	100	114	0.0950	0.1461	0.2178	0.3334	0.4585	0.6165	0.8128	1.0820
	125	140	0.1156	0.1769	0.2624	0.3986	0.5443	0.7262	0.9500	1.2535
	150	168	0.1378	0.2102	0.3105	0.4688	0.6366	0.8445	1.0978	1.4382

Table 8: Scaling factor to one meter of Armaflex® DS

Copper pipe size (in)	Steel Pipe, DN	ID Insulation (mm)	Wall Thickness (mm)							
			6	9	13	19	25	32	40	50
1/4		6	0.0102	0.0191	0.0349	0.0672	0.1096	0.1719	0.2601	0.3958
3/8	6	10	0.0136	0.0242	0.0423	0.0779	0.1237	0.1900	0.2827	0.4241
1/2		12	0.0153	0.0267	0.0459	0.0833	0.1308	0.1991	0.2941	0.4383
5/8	8	15	0.0178	0.0305	0.0515	0.0913	0.1414	0.2126	0.3110	0.4595
3/4		20	0.0221	0.0369	0.0606	0.1048	0.1590	0.2352	0.3393	0.4948
7/8	15	22	0.0238	0.0394	0.0643	0.1101	0.1661	0.2443	0.3506	0.5089
1		25	0.0263	0.0433	0.0698	0.1182	0.1767	0.2579	0.3676	0.5301
1 1/8	20	28	0.0288	0.0471	0.0754	0.1262	0.1873	0.2714	0.3845	0.5513
1 1/4		32	0.0322	0.0522	0.0827	0.1370	0.2015	0.2895	0.4072	0.5796
1 3/8	25	35	0.0348	0.0560	0.0882	0.1450	0.2121	0.3031	0.4241	0.6008
1 1/2		38	0.0373	0.0598	0.0937	0.1531	0.2227	0.3167	0.4411	0.6220
1 5/8	32	42	0.0407	0.0649	0.1011	0.1638	0.2368	0.3348	0.4637	0.6503
1 7/8	40	48	0.0458	0.0725	0.1121	0.1800	0.2580	0.3619	0.4976	0.6927
2 1/8		54	0.0509	0.0802	0.1231	0.1961	0.2792	0.3891	0.5316	0.7351

2 3/8	50	60	0.0560	0.0878	0.1342	0.2122	0.3004	0.4162	0.5655	0.7775
2 5/8		67	0.0619	0.0967	0.1470	0.2310	0.3252	0.4479	0.6051	0.8270
3	65	76	0.0696	0.1081	0.1636	0.2552	0.3570	0.4886	0.6560	0.8906
3 1/8		80	0.0729	0.1132	0.1709	0.2659	0.3711	0.5067	0.6786	0.9189
3 1/2	80	89	0.0806	0.1247	0.1875	0.2901	0.4029	0.5474	0.7295	0.9825
	90	102	0.0916	0.1412	0.2114	0.3250	0.4489	0.6062	0.8030	1.0744
4 1/4		108	0.0967	0.1489	0.2224	0.3411	0.4701	0.6333	0.8369	1.1168
	100	114	0.1018	0.1565	0.2334	0.3572	0.4913	0.6605	0.8708	1.1592
	125	140	0.1238	0.1896	0.2812	0.4271	0.5832	0.7781	1.0179	1.3430
	150	168	0.1476	0.2252	0.3326	0.5023	0.6821	0.9048	1.1762	1.5410

Table 9: Scaling factor to one meter of Armaflex® FRV

Copper pipe size (in)	Steel Pipe, DN	ID Insulation (mm)	Wall Thickness (mm)							
			6	9	13	19	25	32	40	50
1/4		6	0.0129	0.0242	0.0442	0.0851	0.1388	0.2178	0.3295	0.5014
3/8	6	10	0.0172	0.0306	0.0535	0.0987	0.1567	0.2407	0.3581	0.5372
1/2		12	0.0193	0.0338	0.0582	0.1055	0.1656	0.2521	0.3725	0.5551
5/8	8	15	0.0226	0.0387	0.0652	0.1157	0.1791	0.2693	0.3940	0.5820
3/4		20	0.0279	0.0467	0.0768	0.1327	0.2015	0.2980	0.4298	0.6267
7/8	15	22	0.0301	0.0500	0.0815	0.1395	0.2104	0.3094	0.4441	0.6447
1		25	0.0333	0.0548	0.0885	0.1497	0.2238	0.3266	0.4656	0.6715
1 1/8	20	28	0.0365	0.0596	0.0954	0.1599	0.2373	0.3438	0.4871	0.6984
1 1/4		32	0.0408	0.0661	0.1048	0.1735	0.2552	0.3667	0.5157	0.7342
1 3/8	25	35	0.0441	0.0709	0.1117	0.1837	0.2686	0.3839	0.5372	0.7611
1 1/2		38	0.0473	0.0757	0.1187	0.1939	0.2820	0.4011	0.5587	0.7879
1 5/8	32	42	0.0516	0.0822	0.1280	0.2075	0.2999	0.4240	0.5874	0.8237
1 7/8	40	48	0.0580	0.0919	0.1420	0.2280	0.3268	0.4584	0.6303	0.8774
2 1/8		54	0.0645	0.1015	0.1560	0.2484	0.3537	0.4928	0.6733	0.9312
2 3/8	50	60	0.0709	0.1112	0.1699	0.2688	0.3805	0.5272	0.7163	0.9849
2 5/8		67	0.0784	0.1225	0.1862	0.2926	0.4119	0.5673	0.7664	1.0476
3	65	76	0.0881	0.1370	0.2072	0.3232	0.4522	0.6189	0.8309	1.1281
3 1/8		80	0.0924	0.1434	0.2165	0.3368	0.4701	0.6418	0.8595	1.1640

3 1/2	80	89	0.1021	0.1579	0.2374	0.3675	0.5104	0.6934	0.9240	1.2445
	90	102	0.1160	0.1789	0.2677	0.4117	0.5685	0.7679	1.0171	1.3609
4 1/4		108	0.1225	0.1886	0.2817	0.4321	0.5954	0.8022	1.0601	1.4147
	100	114	0.1289	0.1982	0.2956	0.4525	0.6223	0.8366	1.1031	1.4684
	125	140	0.1569	0.2401	0.3562	0.5410	0.7387	0.9856	1.2893	1.7012
	150	168	0.1869	0.2853	0.4214	0.6362	0.8640	1.1461	1.4899	1.9519

Table 10: Scaling factor to one square meter of seven Armaflex® sheet product

	Wall Thickness (mm)									
	6	9	13	19	25	30	32	35	40	50
Armaflex® Class 0	0.2640	0.3960	0.5720	0.8360	1.1000	1.3200	1.4080	1.5400	1.7600	2.2000
Armaflex® Class 1	0.2520	0.3780	0.5460	0.7980	1.0500	1.2600	1.3440	1.4700	1.6800	2.1000
Armaflex® DS	0.2700	0.4050	0.5850	0.8550	1.1250	1.3500	1.4400	1.5750	1.8000	2.2500
Armaflex Endura®	0.3600	0.5400	0.7800	1.1400	1.5000	1.8000	1.9200	2.1000	2.4000	3.0000
Armaflex® AMP	0.3600	0.5400	0.7800	1.1400	1.5000	1.8000	1.9200	2.1000	2.4000	3.0000
Armaflex® Class 0 Plus	0.2640	0.3960	0.5720	0.8360	1.1000	1.3200	1.4080	1.5400	1.7600	2.2000
Armaflex® FRV	0.3420	0.5130	0.7410	1.0830	1.4250	1.7100	1.8240	1.9950	2.2800	2.8500

Additional Environmental Information

Indoor environment

Armaflex® insulation products are safe to use in an indoor environment. They are certified to strict indoor air quality standards such as UL Environment GREENGUARD Gold. They also meet or exceed all applicable industry performance.

Building use stage benefits

In the following building use phase example, calculation rules based on EN-ISO 12241 is used to calculate the energy saved, with and without insulation, and determines the amount of time the insulation must be in service so as to recover the life cycle energy (primary energy demand, PED). The product used for following example is Armaflex® Class 0. Table 11 shows five sets of working temperature and the corresponding insulation thickness as recommended by ASHRAE 90.1 to calculate the recovery time. The assumptions for this calculation are ambient temperature of 32°C, indoors and insulation without facing.

Table 11: Time needed to recover Primary Energy Demand (PED) of Armaflex® Class 0 for pipe application

Fluid Operating Temp. (°C)	Steel Pipe, DN	ASHRAE Recommended Thickness (mm)	Selected Thickness (mm)	PED for one m, (MJ)	Heat loss Bare Pipe (W/m)	Heat loss insulated Pipe (W/m)	Energy saved by one m (W/m)	Converted to PED saved (W/m)	Hours in-situ needed to recover the PED	Days in-situ needed to recover the PED
-10	50	25	25	22.36	82.78	13.23	69.55	79.98	77.7	3.2
7	50	25	25	22.36	46.76	8.06	38.7	44.51	139.6	5.8
60	50	38	40	42.09	59.42	7.78	51.64	59.39	196.9	8.2
80	50	51	55	66.56	114.30	11.17	103.13	118.60	155.9	6.5
100	50	76	80	117.85	177.00	14.09	162.91	187.35	174.7	7.3

Table 12 presents another example of calculating energy saved, with and without insulation, and the insulation service time required so as to recover the life cycle energy (primary energy demand, PED). This is based on an ice storage tank with fluid temperature at -6.7°C and an indoor ambient temperature of 32°C.

Table 12: Time needed to recover Primary Energy Demand (PED) of Armaflex® Class 0 for large tank application

Fluid Operating Temp. (°C)	Selected Thickness (mm)	PED for one m^2, (MJ)	Heat loss bare tank (W/m^2)	Heat loss insulated tank (W/m^2)	Energy saved by one m^2 (W/m^2)	Converted to PED saved (W/m^2)	Hours in-situ needed to recover the PED	Days in-situ needed to recover the PED
-6.7	50	167.47	346.80	24.63	322.17	370.50	125.6	5.2

References

ISO 12241 – Thermal Insulation for building equipment and industrial installations – Calculation rules

ISO 14025 - ISO14025:2011-10, Environmental labels and declarations - Type III environmental declarations - Principles and procedures

ISO 14040 - Environmental management - Life cycle assessment - Principles and framework

ISO 14044 - Environmental management - Life cycle assessment – Requirements and guidelines

SimaPro - LCA Computer Software http://www.pre-sustainability.com/

EPD Development

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Armaflex®

Armaflex® Class 0, Armaflex® Class 1, Armaflex® DS, Armaflex Endura®,
Armaflex® AMP, Armaflex® Class 0 Plus & Armaflex® FRV

According to ISO 14025

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