**ENVIRONMENTAL PRODUCT DECLARATION**

# AP/ARMAFLEX®, ARMAFLEX® AC CLASS 0

ARMACELL INSULATION FOR INDUSTRIAL AND BUILDING INSTALLATION

armacell
MAKING A DIFFERENCE AROUND THE WORLD

Armacell focus is on creating sustainable value-to be the global leader inproviding innovative technical insulation solutions and components to save energy and make a difference around the world.

Through a portfolio principally composed of energy-saving products and solutions, efforts to boost the circular economy, better resource management and multiple environment a initiatives, Armacell is helping to protect our planet.

Environmental protection is integrated into the company's manufacturing facilities and is part of its daily business. Armacell is committed to improving sustainability indifferent end markets and measures its own operations by the same standards protect our planet.

*For more information visit www.armacell.com*

UL CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION UL.COM/EPD

Environment

UL

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MAKING A DIFFERENCE AROUND THE WORLD

CERTIFIED
ENVIRONMENTAL PRODUCT DECLARATION
UL.COM/EPD

**AP/ArmaFlex, ArmaFlex AC Class 0**

**According to ISO 14025 and ISO 21930:2017**

| | |
|---|---|
| EPD PROGRAM AND PROGRAM OPERATOR NAME, ADDRESS, LOGO, AND WEBSITE | UL Solutions https://www.ul.com/<br>333 Pfingsten Road Northbrook, IL 60611 https://spot.ul.com |
| GENERAL PROGRAM INSTRUCTIONS AND VERSION NUMBER | General Program Instructions v.2.5 March 2020 |
| MANUFACTURER NAME AND ADDRESS | Armacell Middle East Company W.L.L<br>Building 1284, Block 115, Road 1516, Bahrain International Investment Park, Salman Industrial City, Kingdom of Bahrain |
| DECLARATION NUMBER | 4791321445.101.1 |
| DECLARED PRODUCT &<br>FUNCTIONAL UNIT OR DECLARED UNIT | AP/ArmaFlex, ArmaFlex AC Class 0<br>1m$^2$ for Non-piping applications with service time of 75 years with packaging included.<br>1m for Piping applications with service time of 75 years with packaging included. |
| REFERENCE PCR AND VERSION NUMBER | Product Category Rules for Building-Related Products and Services<br>Part A: Life Cycle Assessment Calculation Rules and Report Requirements, Standard 10010, Version 4.0<br>Part B: Mechanical, Specialty, Thermal, and Acoustic Insulation Product EPD Requirements, UL 10010–03,version 1.0 |
| DESCRIPTION OF PRODUCT APPLICATION/USE | Original, fiber-free, flexible elastomeric pipe, valve and duct insulation for reliable protection against condensation, mould and energy loss. |
| PRODUCT RSL DESCRIPTION (IF APPL.) | 75 years |
| MARKETS OF APPLICABILITY | Western Asia, Middle East, and Africa |
| DATE OF ISSUE | July 15, 2024 |
| PERIOD OF VALIDITY | 5 years |
| EPD TYPE | [product-Specific] |
| RANG OF DATASET VARIABILITY | N/A |
| EPD SCOPE | [Cradle to installation with end of life] |
| YEAR(S) OF REPORTED PRIMARY DATA | January 2023—December 2023 |
| LCA SOFTWARE& VERSION NUMBER | SimaPro 9 |
| LCI DATABASE(S) & VERSION NUMBER | Ecoinvent 3.9 |
| LCIA METHODOLOGY& VERSION NUMBER | CML-IA (baseline) |
| The PCR review was conducted by: | UL Solutions<br>PCR Review Panel<br>epd@ul.com |
| This declaration was independently verified in accordance with ISO 14025: 2006.<br>□ INTERNAL ☑EXTERNAL | Cooper McCollum, UL Solutions |
| This life cycle assessment was conducted in accordance with ISO 14044 and the reference PCR by: | Ecovane Environmental Co,. Ltd |
| This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by: | Thomas P. Gloria, Industrial Ecology Consultants |

Environment

LIMITATIONS

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; the level of accuracy in estimation of effect differs for any particular product line and reported impact.

Comparability: EPDs from different programs may not be comparable. Full conformance with a PCR allows EPD comparability only when all stages of a life cycle have been considered. However, variations and deviations are possible". Example of variations: Different LCA software and background LCI datasets may lead to differences results for upstream or downstream of the life cycle stages declared.

# 1. Product Definition and Information

## 1.1. Description of Company/Organization

As the inventors of flexible foam for equipment insulation and a leading provider of engineered foams, Armacell develops innovative and safe thermal, acoustic and mechanical solutions that create sustainable value for its customers. Armacell's products significantly contribute to global energy efficiency making a difference around the world every day. As a multi-materials and multi-solutions company, it operates two main businesses: Advanced Insulation and Engineered Foams, with a focus on insulation materials for technical equipment, high-performance foams for high-tech and lightweight applications and next generation aerogel blanket technology.

Armacell is a truly global company managed from its corporate headquarters in Luxembourg and regional head offices in Germany, the USA and Singapore. It pursues an international growth strategy with 24 manufacturing plants in 16 countries on four continents. The company's commitment to environmental protection is part and parcel of its corporate philosophy and business strategy. After all, Armacell's insulation solutions play a key role in protecting equipment against energy losses in millions of applications worldwide.

Our plants comply with the following standards:

- ISO 45001:2018 - Occupational Health and Safety Management System
- ISO 14001:2015 - Environmental Management System
- ISO 9001:2015 - Quality Management System

## 1.2. Product Description

**Product Identification**

Armaflex insulation materials are professional, highly-flexible, closed cell elastomeric foam insulation (FEF) 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. FEFs made of cross-linked elastomer are supplied as sheets, tubes and shaped pieces. Although products with self-adhesive backings/closures are available, these variations are not included in the study.

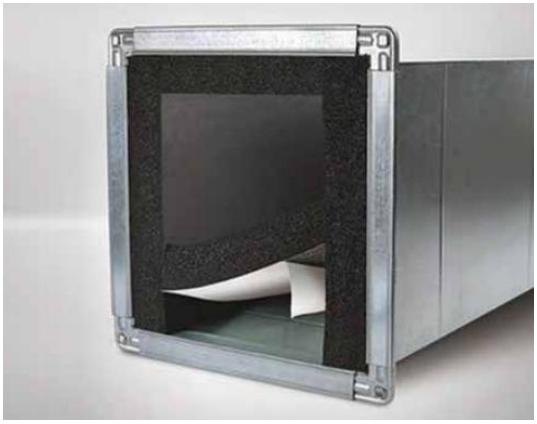


Figure 1 Armaflex insulation products

**Product Specification**

There are two types of Armaflex insulation products in this LCA study, namely ArmaFlex AC Class 0 and AP/ArmaFlex.

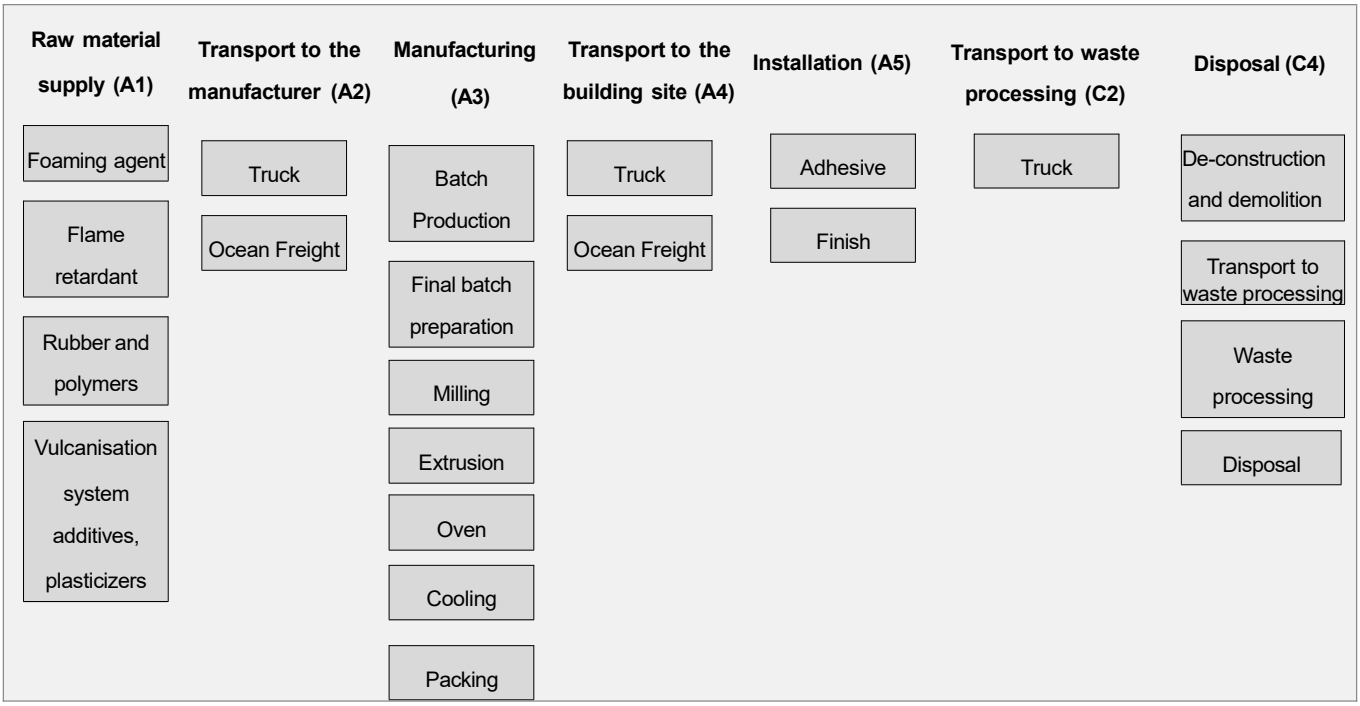
Table 1 Technical data of ArmaFlex AC Class 0 and AP/ArmaFlex insulation products

| Parameter | Unit | ArmaFlex AC Class 0 | AP/ArmaFlex |
|---|---|---|---|
| Density | $Kg/m^3$ | 50 | 48 |
| Maximum service temperature | ºC | 110<br>85 (if sheet is glue to the object with its whole surface) | 105<br>85 (if sheet is glue to the object with its whole surface) |
| Minimum service temperature | ºC | -50 | -50 |
| Thermal conductivity @0ºC | W/(m.K) | ≤ 0.040 | ≤ 0.035 |
| Water vapor diffusion resistance | - | ≤0.05 Perm Inch<br>Tested acc.to ASTM E 96, Procedure A | ≤0.05 Perm Inch<br>Tested acc.to ASTM E 96, Procedure A |

| | | | |
|---|---|---|---|
| Fire performance | | - Surface Spread of Flame: Class 0; BS 476 Part6&7<br>- Fire propagation Index: Index of overall performance, I≤12; Sub-index i ≤6; BS 476 Part6<br>- Flammability: V-0, FM4924; UL 94<br>- Practical fire behavior: does not generate flaming droplets. | - Reaction to fire: UL723; Tested acc.to ASTM E84<br>- Practical fire behavior: does not generate flaming droplets. |

**Flow Diagram**

Figure 2 Technical data of Armacell's insulation product flow diagram




**Product-Specific EPD**

This declaration covers ArmaFlex AC Class 0 and AP/ArmaFlex. The allocation of energy and material usage within the production site was carried out based on the average annual mass ratio.

## 1.3. Application

Armacell's products and solutions are used to insulate pipes, air ducts and vessels including fittings and flanges of industrial installations and building equipment. Its functions include:

- Condensation control, energy saving and noise control in refrigeration and air conditioning equipment and process plants.

- Energy saving according to local energy saving laws, prevention of heat loss and noise reduction of heating and plumbing systems.

- Condensation control and noise reduction in service-water and waste-water systems.

- Condensation control, energy saving and noise control in refrigeration and air conditioning equipment in the ship-building sector.

## 1.4. Declaration of Methodological Framework

In this project, a full LCA approach was considered with some simplification on data modeling using generic data for most background systems. The EPD analysis uses a cradle-to-installation with end of life system boundary. No known flows are deliberately excluded from this EPD.

To calculate the LCA results for the product maintenance stage, a 75-year reference service life (RSL) was assumed for the declared products.

Additional details on assumptions, cut-offs and allocation procedures can be found in section 2.10, 2.5, and 2.4 respectively.

## 1.5. Technical Data

The chart below lists all technical data for Armacell's products.

Table 2 Technical data for Armacell Insulation

| Product | ArmaFlex AC Class 0 | AP ArmaFlex |
|---|---|---|
| Brief description | ● ArmaFlex AC Class 0 is a flexible insulation material that reliably protects against water vapour ingress due to its closed-cell structure. No additional water vapour barrier is required. | ● Highly-flexible, closed-cell insulation material with high water vapour diffusion resistance, low thermal conductivity and built-in Microban antimicrobial protection. |
| Material type | ● Elastomeric foam based on synthetic rubber. | ● Elastomeric foam based on synthetic rubber. Factory-made flexible elastomeric foam (FEF) according to EN 14304 |
| Water absorption by volume | ● ≤5%<br>● ASTM C 209 | |

| | | |
|---|---|---|
| Chemical resistance | ● Excellent resistance to ozone, oil and chemicals (consult product test list). | |
| UV resistance | ● For UV protection, ArmaFinish Paint 99 or Arma-Cheke Silver 350 covering system is required. For outside use. ArmaFlex should be protected with ArmaFinish Paint or Arma-Chek covering within 3 days of installation. | ● Protection against UV-radiation is necessary. |
| Environmental aspect | ● Zero ODP and GWP. | ● Excellent resistance to ozone, oil and chemicals (consult product test list). |
| Storage | ● Material shall be stored in dry, clean rooms at normal relative humidity (50% to 70% and ambient temperature[0 °C to 35 °C]. | ● Self-adhesive tapes, self-adhesive sheets, self-adhesive tubes: 1 year<br>● Can be stored in dry.clean rooms at normal relative humidity(50% to70%) and ambient temperature (0°C-35 °C). |
| Shelf (storage life) | ● Self-adhesive tapes,self-adhesive sheets, self-adhesive tubes: 1 year | |
| Antimicrobial behaviour | | ● In-built Microban, active antimicrobial protection: No fungal growth observed<br>● Testing acc. To ASTM E 2180-12 |

## 1.6. Properties of Declared Product as Delivered

According to Armacell Bahrain, Armacell's products (ArmaFlex Class 0, AP ArmaFlex) are consumed in Nigeria, South Africa, Kenya, and other African countries, Saudi Arabia, Bahrain, United Arab Emirateds and other western Asian countries.

Table 3 The market ratio of Armacell Insulation Products

| Market region | Country | ArmaFlex AC Class 0 | AP/ArmaFlex |
|---|---|---|---|
| Western Asia | Utd.Arab Emir. | 8.76% | 76.20% |
| | Saudi Arabia | 51.31% | 5.88% |
| | Bahrain | 15.09% | 7.88% |
| | Oman | 0.62% | 5.77% |
| | Kuwait | 3.65% | 3.66% |
| | Jordan | 1.09% | 0.01% |
| | Qatar | 0.00% | 0.11% |

| | | | |
|---|---|---|---|
| Africa | South Africa | 4.50% | 0.00% |
| | Nigeria | 10.78% | 0.34% |
| | Kenya | 0.28% | 0.00% |
| | Mauritius | 1.09% | 0.00% |
| | Ghana | 0.31% | 0.00% |
| | Seychelles | 0.13% | 0.00% |
| | Tanzania | 0.19% | 0.00% |
| Rest market | | 2.20% | 0.15% |

*Note: The rest markets include Pakistan, Turkey, etc.

### 1.7. Material Composition

This EPD report declares two products from Armacell, namely ArmaFlex AC Class 0, AP ArmaFlex. The raw materials of the two series of insulation products include blowing agent, fillers and pigments, flame retardant, rubber and polymers, vulcanisation system additives and plasticizers. The following table displays the composition split into functional substance groups.

Table 4 Composition/formulation of Armacell Insulation

| Composition | ArmaFlex AC Class 0 | AP/ArmaFlex |
|---|---|---|
| Blowing Agent | 13% | 15% |
| Fillers and pigments | 3% | 29% |
| Flame Retarder | 33% | 9% |
| Rubber and polymers | 24% | 23% |
| Vulcanisation system additives, plasticisers | 27% | 24% |

## 2. Methodological Framework

### 2.1. Declared Unit

In this study, the declared units for the two products is defined as 1m of insulation product for Piping applications and 1m$^2$ for Non-piping applications with service time of 75 years with packaging included. Parameters per declaration unit that support the calculation of the LCA results are also depicted in table 5 below.

Table 5 Additional declared unit parameters of Armacell's products

| Name | Value | | Unit |
|---|---|---|---|
| | ArmaFlex AC Class 0 | AP/ArmaFlex | |
| Non-piping applications | 1 | 1 | m$^2$ |
| Piping applications | 1 | 1 | m |

## 2.2. System Boundary

This study of Armacell's products includes life cycle information from cradle to installation with end of life. The product stage for tubes, sheets and rolls includes extraction and processing of raw materials, transportation to the factory and manufacturing processes with packaging and etc. The construction process stage includes transportation of insulation product to the building site from the factory and the installation phase. The end of life stage includes transportation of waste products to the final disposition site and disposal. Over through the life cycle stages of products, resources of energy and materials used together with emissions to soil, water and air are accounted for in the calculations of the Impact Assessment. Building's additional operational energy and water use are considered outside of the scope of this study:

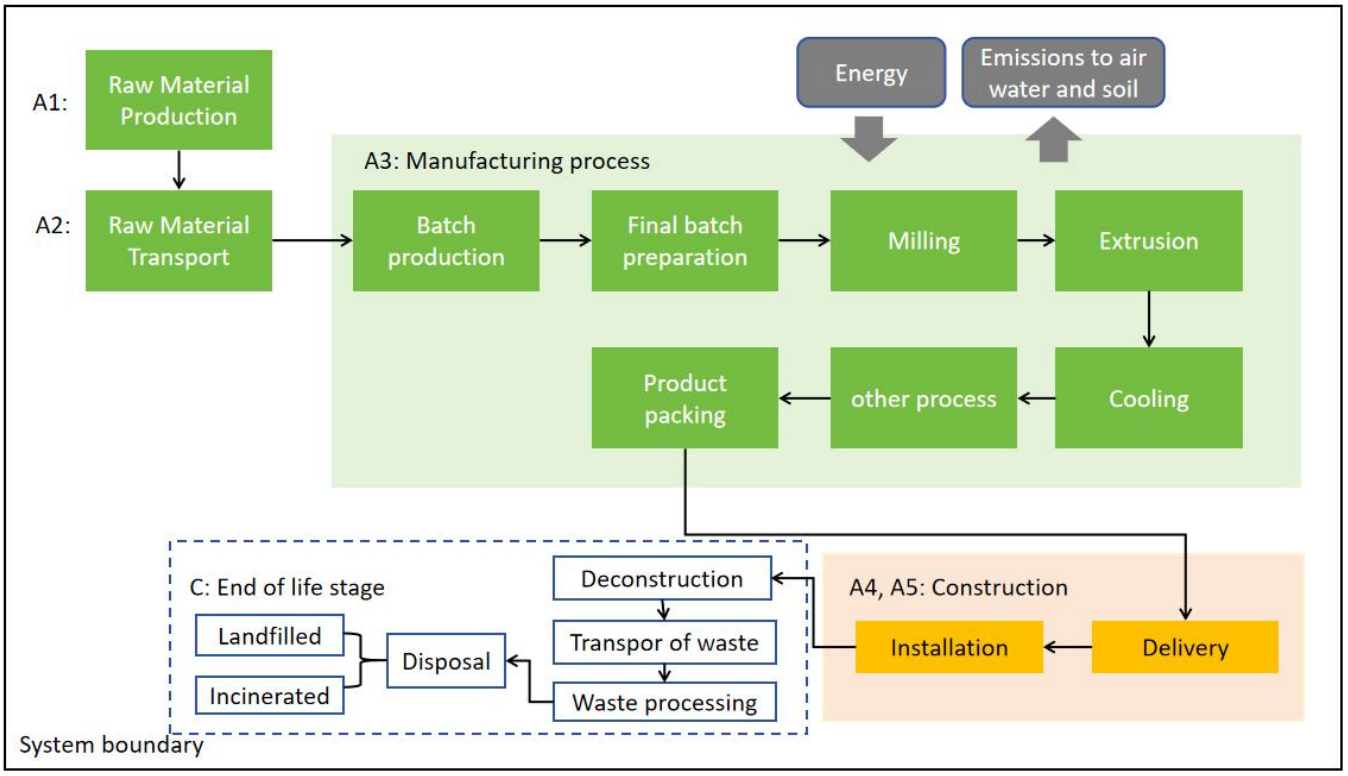



Figure 3 System boundary of insulation products

## 2.3. Product Specific Calculations for Use Phase

In the following building use phase example, calculation rules based on EN-ISO 12241 with reference to "PCR by UL Environment (ULE): Product Category Rules for Building-Related Products and Services, Part B: Mechanical, Specialty, Thermal, and Acoustic Insulation Product EPD Requirements." 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 AP/Armaflex® tube, and AP/Armaflex® sheet and roll.

Table 6 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 32oC, indoors and insulation without facing. For simplification the thermal conductivity was set to be 0.035W/(m.K).

Table 7 below 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 -6.7oC and an indoor ambient temperature of 32oC.

Table 6 Time needed to recover Primary Energy Demand (PED) of AP/Armaflex® for tube application

| Fluid Operating Temp. (oC) | 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 | 54.35 | 82.78 | 13.23 | 69.55 | 79.98 | 188.8 | 7.9 |
| 7 | 50 | 25 | 25 | 54.35 | 46.76 | 8.06 | 38.7 | 44.51 | 339.2 | 14.1 |
| 60 | 50 | 38 | 40 | 102.31 | 59.42 | 7.78 | 51.64 | 59.39 | 478.6 | 19.9 |
| 80 | 50 | 51 | 55 | 161.78 | 114.30 | 11.17 | 103.13 | 118.60 | 378.9 | 15.8 |
| 100 | 50 | 76 | 80 | 286.47 | 177.00 | 14.09 | 162.91 | 187.35 | 424.8 | 17.7 |

Table 7 Time needed to recover Primary Energy Demand (PED) of AP/Armaflex® sheet and roll for large tank application

| Fluid Operating Temp. (oC) | Selected Thickness (mm) | PED for one m2, (MJ) | Heat loss bare tank (W/m2) | Heat loss insulated tank (W/m2) | Energy saved by one m2 (W/m2) | Converted to PED saved (W/m2) | Hours in-situ needed to recover the PED | Days in-situ needed to recover the PED |
|---|---|---|---|---|---|---|---|---|
| -6.7 | 50 | 407.09 | 346.80 | 24.63 | 322.17 | 370.50 | 305.2 | 12.7 |

## 2.4. Reference Service life and Estimated Building Service Life

The reference service life of Armacell products is 75 years.

## 2.5. 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.

**Multi-input processes**

For data sets in this study, the allocation of the inputs from coupled processes is generally carried out via the mass and volume. The consumption of raw materials is allocated by mass ratio. The transportation of raw materials is allocated by mass. For foam production, the total consumption of energy and water during manufacturing is equally allocated to per unit volume of foam product.

**Multi-output processes**

In this study, there is no other by products produced from the production line, hence, there is quite little occasion that required allocation for multi-output processes. One allocation occurs on the environmental emissions allocation, especially in the area of waste treatment. The environmental emissions of masterbatch and forming product are allocated by mass and volume to each unit product respectively. In the end of life stage, the allocation within the disposal scenario follows mass allocation, which applies to waste treatment process inventory adopted from Ecoinvent data.

## 2.6. Cut-off Rules

The following procedure was followed for the exclusion of inputs and outputs:

- All inputs and outputs to a (unit) process will be included in the calculation for which data is available. Data gaps may be filled by conservative assumptions with average or generic data. Any assumptions for such choices will be documented;
- In case of insufficient input data or data gaps for a unit process, according to the PCR requirement, the cut-off criteria chosen is 1% of renewable and non-renewable primary energy usage and 1% of the total mass of that unit process. The total neglected input flows of the cradle to installation with end of life stage, e.g. per module A1-A3, A4-A5, C1, C2 and C4 shall be a maximum of 5% of energy usage and mass.

Table 8 Cut off flows

| Flow name | Process stage | Mass % | Total Mass % |
|---|---|---|---|
| Printing ink | production | ≤0.002% | ≤0.002% |
| Solvent For Ink | production | ≤0.006% | ≤0.008% |

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

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

Material and energy flows known to have the potential to cause significant emissions into air and water or soil related to the environmental indicators of this study will be included in the assessment. According to review of the Material Safety Data Sheet (MSDS) and relevant physical, chemical and other information of the flows listed in table above, no significant negative emission to the environment from above listed flows is identified.

## 2.7. Data Source

In this study, generic data for certain processes were sourced from the databases in SimaPro 9. In case of data gaps from the Ecoinvent database, alternative databases were referred to, including ELCD, Japanese Input and output database, IVAM (Dutch) and etc., so as to avoid using dummy (empty) processes in this study, and also to utilise as much regional data as possible in some cases.

## 2.8. Data Quality

The data quality requirements for this study were as follows:

- Existing LCI data were, at most, 10 years old. Newly collected LCI data were current or up to 5 years old.
- The LCI data related to the geographical locations in which the processes occurred, e.g. electricity and transportation data from China.
- The technology represented the average technologies at the time of data collection

In the study the key parameters for producer-specific foreground data are based on yearly production amounts and extrapolations of measurements on specific machines and plants. The production data from the plant in Bahrain refer to an average of the year 2023, and the production data from the plant in Panyu (China) refer to an average of the year 2019. The input data of raw material transportation refer to an average of production scenario. Most of the necessary life cycle inventories for the basic materials are available in the Simapro database 3.9. Further LCIs for materials of the supply chain of the basic materials are approximated with LCIs of similar materials or estimated by the combination of available LCIs.

## 2.9. Period under Review

The production data from the plant in Bahrain refer to an average of the year 2023 (from January 2023 to December 2023) , and the production data from the plant in Panyu (China) refer to an average of the year 2019,which all based on 12 consecutive moths of averaged data.

## 2.10. Comparability and Benchmarking

No comparisons or benchmarking are included in this EPD. LCA results across EPDs can be calculated with different background databases, modeling assumptions, geographic scope and time periods, all of which are valid and acceptable according to the Product Category Rules (PCR) and ISO standards. The user of the EPD should take care when comparing EPDs from different companies. Assumptions, data sources, and assessment tools may all impact the uncertainty of the final results and make comparisons misleading.

## 2.11. Estimates and Assumptions

The main assumptions of this LCA study are as follows：

- Since the production process of masterbatch is basically the same for each product type, the input and output of masterbatch production processes for different product types are considered the same (except some raw materials). And the input and output data on Panyu site are adopted to report for masterbatch produced both in Muenster (Armacell Germany) and Panyu (Armacell China), which is considered not significant influenced by variation of production location.
- Since there is no accurate input data of packaging and particulate emissions, it is simplified that, the input data of packaging and output data of waste emission of particulate from production process for different series are the same and substituted by the data from Panyu (China) site for modeling.
- The transportation distance of packaging and auxiliary materials, like lubricating oil is assumed to be 15 km as more accurate data is unavailable, a sensitivity analysis is conducted.
- Distance of raw material and product transportation including land transportation and oversea transportation uses estimated figure and a sensitivity analysis is conducted.
- Consumption of adhesive used for product installation is based on assumption of types and quantity, and a sensitivity analysis is conducted.
- Deconstruction of product during the disposal stage was considered through manual operation, and the removal of product was omitted from modelling.
- The distance from construction site to incineration site was assumed 50 km.
- Installation will generated 1% scrap and scrap applies the same end-of-life disposal scenario as the dismantled product at end-of-life.

## 2.12. Units

SI units are used for all LCA results of Armacell’s products.

# 3. Life Cycle Assessment Scenarios

## 3.1. Manufacturing

The Armaflex insulation products (ArmaFlex AC Class 0 and AP/ArmaFlex) share similar manufacturing processes and life cycle stage, with the key difference on performance related to fire resistance.

Armaflex products are manufactured in a pressureless production process. In the first step, a homogenous compound (called MasterBatch) is produced with rubber, additives, ancillary materials, blowing and vulcanization agents. This is done on the rolling mill or in the internal mixer followed by the rolling mill. The MasterBatches are centrally produced by compounding plants in Panyu(China) and Muenster(Germany), and then delivered to the finishing plant in Bahrain. Extruders are used to process the compounds of Masterbatch to produce raw profiles with defined dimensions, which will be further foamed into final insulation products with various dimensions.

The raw profiles after the Masterbatch will enter the forming process. In foam production, vulcanization and blowing processes run alongside each other. Both reactions are regulated by temperature control. Recipe and temperature control determine the properties of the foam. After forming process, the products are cooled and dried and get ready for packaging, quality check and delivery.

A Flowchart depicting the production process stages of Armacell’ s insulation products are shown in Figure below. For simplification purpose, auxiliary processes considered in the LCA but not shown in the flow chart below include:

- Transportation of MasterBatches from China and Germany to Bahrain;
- Waste liquor and gas treatment;
- Supply of natural gas/water/electricity

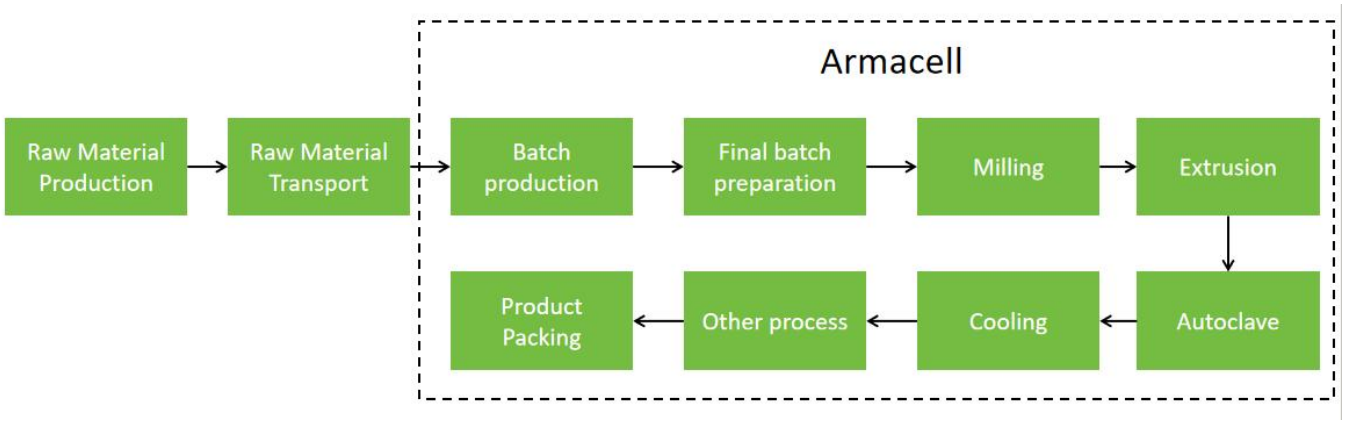



Figure 4 Production Process Flowchart of Armaflex insulation products

## 3.2. Packaging

There are three main kinds of packaging materials, carton (paper), pallets(wood), plastic film (plastic). According to the data from Ecoinvent, the amount of biogenic carbon uptake of paper during biomass growth stage is approximately 1.23 kg CO2/kg, which is the raw material of cardboard. The amount of biogenic carbon uptake of wood used in pallet over its growth cycle is approximately 1.815kg CO2 per kg of pallet. And there is no biogenic carbon uptake of plastic. On account of the consumption of packaging material of insulation product, the amount of biogenic carbon contained within the packaging material of 1 m3 of different series of insulation product is 4.877 kg CO2. And the amount of biogenic carbon contained within the packaging material of different declared units of the two products are declared in section 6.

Once packaging material's service life ends, biogenic carbon will be emitted back to atmosphere. Determining biogenic carbon emissions from packaging material is not a trivial calculation, and depends on how it is disposed. According to the market ratio and the waste disposal scenarios, of that 4.877kg CO2 contained within the packaging material of 1 m3 of insulation product, the following can now be calculated:

- ArmaFlex AC Class 0: 3.016 kg CO2 remains stored in recycled packaging materials; AP/ArmaFlex: 3.533kg CO2 remains stored in recycled packaging materials;
- ArmaFlex AC Class 0: 1.861 kg CO2 is emitted into the atmosphere either directly or from flaring or combustion of methane from landfill; AP/ArmaFlex: 1.344 kg CO2 is emitted into the atmosphere either directly or from flaring or combustion of methane from landfill.

## 3.3. Transportation

Transportation stage only includes foaming products transportation. The transportation of raw material and auxiliary supplies are considered in the stage of "raw material acquisition" and "manufacturing". The transportation of masterbatch are also considered in the stage of "raw material acquisition".

Road and oceanic transportation distance for product delivery is estimated with reference from external resources. A sensitivity analysis was also conducted by changes of assumption of various transportation distances. In this study a default value for the distance is given in table below.

Table 9. Transport to the building site (A4)

| **Name** | **Value** | | **Unit** |
|---|---|---|---|
| | **Road** | **Ocean** | |
| Fuel type | Diesel | Heavy Oil | |
| Liters of fuel | 31.11 l/100km | 12.483 t/100km | L /100km or T/100km |
| Vehicle type | Lorry (32t) | Transoceanic Ship | |

| | | | |
|---|---|---|---|
| | | (50000 dwt) | |
| Transport distance | AP/ArmaFlex: 45.35<br>ArmaFlex AC Class 0: 270.25 | AP/ArmaFlex: 460.07<br>ArmaFlex AC Class 0: 2253.88 | km |
| Capacity utilization (including empty runs, mass based | 50% | 100 | % |
| Gross density of products transported | AP/ArmaFlex: 48<br>ArmaFlex AC Class 0: 50 | AP/ArmaFlex: 48<br>ArmaFlex AC Class 0: 50 | kg/m3 |
| Capacity utilization volume factor (factor: =1 or <1 or ≥ 1 for compressed or nested packaging products) | 0.4 | 0.4 | - |

Note: Transport distance (Ocean)uses weighted value, namely, Transport distance (Ocean)=∑market ratio*market distance.

## 3.4. Product Installation

Installation of foam insulation products is a task requiring only a few tools, including one consumable produce, i.e. adhesive specific for foam insulation. The adhesive is used to bind insulation together. Tools like cutting instruments (knife, box-cutter), measuring devices, painting brushes and angle tools are necessary for installation of insulation. As tools are reusable, the consumption of tools is omitted in this study. The amount of adhesive used is 10gram per kilogram product, estimated by armacell.

Table 10. Installation into the building (A5)

| **Name** | **Value** | | **Unit** |
|---|---|---|---|
| Ancillary materials | 0.01 | | kg |
| Net freshwater consumption specified by water source and fate (e.g., X $m^3$ river water evaporated, X $m^3$ city water disposed to sewer) | - | | $m^3$ |
| Other resources | - | | kg |
| Electricity consumption | - | | kWh |
| Other energy carriers | - | | MJ |
| Product loss | 0.01 | | kg/kg |
| Waste materials at the construction site before waste processing, generated by product installation | Waste product: 0.01 | | kg/kg |
| | Waste packaging: see mass of packaging waste specified by type | | $kg/m^3$ |
| Output materials resulting from on-site waste processing (specified by route; e.g. for recycling, energy recovery and/or | Waste product | **Recycling:**<br>AP/ArmaFlex: 0.00724 | kg/kg |

| | | | |
|---|---|---|---|
| disposal) | | ArmaFlex AC Class 0: 0.00618<br>**Disposal:**<br>AP/ArmaFlex: 0.00276<br>ArmaFlex AC Class 0: 0.00382 | |
| | Waste packaging | **Recycling:**<br>AP/ArmaFlex: 0.957<br>ArmaFlex AC Class 0: 0.868<br>**Disposal:**<br>AP/ArmaFlex: 3.37<br>ArmaFlex AC Class 0: 3.46 | kg/m$^3$ |
| Mass of packaging waste specified by type | Paper: 3.943<br>Plastics: 0.382<br>Wood: 0.00265 | | kg/m$^3$ |
| Biogenic carbon contained in packaging | 4.877 | | kg $CO_2$/m$^3$ |
| Direct emissions to ambient air, soil and water | - | | kg |
| VOC emissions | N/A | | µg/m$^3$ |

Note: The VOC emissions shall be determined in accordance to “Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources using Environmental Chambers - version 1.2” CA Specification 01350. Since there are two series of ArmaFlex foam product, biogenic carbon contained in packaging is calculated according to the information of the representative product as default.

## 3.5. Disposal

According to Armacell, the products are consumed mainly in Western Asia, Africa and other regions. The disposal of the used products will adopt a region average disposal mode following literature review. End of life disposal treatment process (C4) and waste recycling process (C3) from ecoinvent will be used in this LCA study. For the waste scenario, 50km of road transportation (C2) from construction site to MSW treatment site was assumed. Deconstruction of product during the disposal stage was considered through manual operation, hence input and output is omitted in deconstruction (C1), and the impact is zero.

Table 11. End of life (C1-C4)

| **Name** | | **Value** | **Unit** |
|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Assumptions for scenario development (description of deconstruction, collection, recovery, disposal method and transportation) | | See description and table above | | |
| Collection process (specified by type) | Collected separately | - | | kg |
| | Collected with mixed construction waste | Roll and sheet (1 $m^2$) | AP/ArmaFlex: 0.808<br>ArmaFlex AC Class 0: 1.386 | kg |
| | | Tube (1 m) | AP/ArmaFlex: 0.195<br>ArmaFlex AC Class 0: 0.256 | |
| Recovery (specified by type) | Reuse | - | | kg |
| | Recycling | Roll and sheet (1 $m^2$) | AP/ArmaFlex: 0.585<br>ArmaFlex AC Class 0: 0.857 | kg |
| | | Tube (1 m) | AP/ArmaFlex: 0.141<br>ArmaFlex AC Class 0: 0.158 | |
| | Incineration with energy recovery | - | | kg |
| | Energy conversion efficiency rate | - | | |
| Disposal (specified by type) | landfill | Roll and sheet (1 $m^2$) | AP/ArmaFlex: 0.223<br>ArmaFlex AC Class 0: 0.529 | kg |
| | | Tube (1 m) | AP/ArmaFlex: 0.0537<br>ArmaFlex AC Class 0: 0.0978 | |
| | Incineration | - | | kg |
| Removals of biogenic carbon (excluding packaging) | | 0 | | kg CO2 |

Note: Since there are two Armacell products, collection process and recovery is calculated according to the information of the

representative product as default.

## 4. Environmental Indicators Derived from LCA

Table 12. Description of the system boundary modules

| | | | | |
|---|---|---|---|---|
| Included modules in the life cycle assessment | Product Stage | X | A1 | raw material supply |
| | | X | A2 | transport to the manufacturer |
| | | X | A3 | manufacturing |
| | Construction Stage | X | A4 | transport to the building site |
| | | X | A5 | installation in the building |
| | Use Stage | MND | B1 | use |
| | | MND | B2 | maintenance |
| | | MND | B3 | repair |
| | | MND | B4 | replacement |
| | | MND | B5 | refurbishment |
| | End of Life Stage | X | C1 | de-construction and demolition |
| | | X | C2 | transport to waste processing |
| | | X | C3 | waste processing |
| | | X | C4 | disposal |
| | Benefits and loads beyond the product system boundary | MND | D | reuse, recovery and/or recycling potentials |
| Note: X=Declared Module, MND=Module not Declared in this LCA study | | | | |

### 4.1. Life Cycle Impact Assessment Results

LCIA provides indicators and basis for analyzing the potential contributions of the resource extractions, usage of material and wastes disposal/emissions in an inventory to a number of potential impacts. According to ISO 14040, Life Cycle Impact Assessment (LCIA) is essentially meant to improve the understanding of the results of the inventory phase.

This LCA follows the UL PCR guideline and use the recommended impact method for the analysis. As almost the two series of insulation products are consumed in Western Asia and Africa, the following default international characterization methods listed in the table below were included in this report.

Table13. Results by stage for ArmaFlex AC Class 0 (1m)

| Impact category | Unit | production | transport of product | installation | deconstruction | transport of waste | Waste processing | disposal |
|---|---|---|---|---|---|---|---|---|

| | | A1-A3 | A4 | A5 | C1 | C2 | C3 | C4 |
|---|---|---|---|---|---|---|---|---|
| Global warming (GWP100a) | kg CO2 eq | 7.64E-01 | 1.30E-02 | 3.25E-02 | 0.00E+00 | 1.78E-02 | 0.00E+00 | 5.19E-03 |
| Ozone layer depletion (ODP) | kg CFC-11 eq | 5.17E-08 | 1.74E-10 | 8.17E-11 | 0.00E+00 | 2.25E-10 | 0.00E+00 | 2.96E-11 |
| Photochemical oxidation | kg C2H4 eq | 1.66E-04 | 4.93E-06 | 6.79E-06 | 0.00E+00 | 3.06E-06 | 0.00E+00 | 1.15E-06 |
| Acidification | kg SO2 eq | 3.21E-03 | 1.57E-04 | 2.00E-05 | 0.00E+00 | 7.04E-05 | 0.00E+00 | 1.34E-05 |
| Eutrophication | kg PO4--- eq | 8.85E-04 | 1.97E-05 | 5.69E-05 | 0.00E+00 | 1.59E-05 | 0.00E+00 | 2.52E-04 |

Table14. Results by stage for ArmaFlex AC Class 0 (1m$^2$)

| Impact category | Unit | production | transport of product | installation | deconstruction | transport of waste | Waste processing | disposal |
|---|---|---|---|---|---|---|---|---|
| | | A1-A3 | A4 | A5 | C1 | C2 | C3 | C4 |
| Global warming (GWP100a) | kg CO2 eq | 4.13E+00 | 7.02E-02 | 1.75E-01 | 0.00E+00 | 9.64E-02 | 0.00E+00 | 2.81E-02 |
| Ozone layer depletion (ODP) | kg CFC-11 eq | 2.79E-07 | 9.38E-10 | 4.41E-10 | 0.00E+00 | 1.22E-09 | 0.00E+00 | 1.60E-10 |
| Photochemical oxidation | kg C2H4 eq | 8.99E-04 | 2.66E-05 | 3.67E-05 | 0.00E+00 | 1.65E-05 | 0.00E+00 | 6.21E-06 |
| Acidification | kg SO2 eq | 1.73E-02 | 8.47E-04 | 1.08E-04 | 0.00E+00 | 3.81E-04 | 0.00E+00 | 7.26E-05 |
| Eutrophication | kg PO4--- eq | 4.78E-03 | 1.06E-04 | 3.08E-04 | 0.00E+00 | 8.61E-05 | 0.00E+00 | 1.36E-03 |

Table 15 Results by stage for AP/ArmaFlex (1 m)

| Impact | Unit | production | transport | installation | deconstruction | transport | Waste | disposal |
|---|---|---|---|---|---|---|---|---|

| category | | | of product | | | of waste | processing | |
|---|---|---|---|---|---|---|---|---|
| | | A1-A3 | A4 | A5 | C1 | C2 | C3 | C4 |
| Global warming (GWP100a) | kg CO2 eq | 5.57E-01 | 1.82E-03 | 2.50E-02 | 0.00E+00 | 1.36E-02 | 0.00E+00 | 2.85E-03 |
| Ozone layer depletion (ODP) | kg CFC-11 eq | 3.03E-08 | 2.42E-11 | 6.22E-11 | 0.00E+00 | 1.71E-10 | 0.00E+00 | 1.63E-11 |
| Photochemical oxidation | kg C2H4 eq | 1.21E-04 | 7.35E-07 | 5.23E-06 | 0.00E+00 | 2.33E-06 | 0.00E+00 | 6.31E-07 |
| Acidification | kg SO2 eq | 2.28E-03 | 2.39E-05 | 1.52E-05 | 0.00E+00 | 5.36E-05 | 0.00E+00 | 7.38E-06 |
| Eutrophication | kg PO4--- eq | 6.13E-04 | 2.94E-06 | 4.39E-05 | 0.00E+00 | 1.21E-05 | 0.00E+00 | 1.39E-04 |

Table 16 Results by stage for AP/ArmaFlex (1 $m^2$)

| Impact category | Unit | production | transport of product | installation | deconstruction | transport of waste | Waste processing | disposal |
|---|---|---|---|---|---|---|---|---|
| | | A1-A3 | A4 | A5 | C1 | C2 | C3 | C4 |
| Global warming (GWP100a) | kg CO2 eq | 2.31E+00 | 7.54E-03 | 1.03E-01 | 0.00E+00 | 5.62E-02 | 0.00E+00 | 1.18E-02 |
| Ozone layer depletion (ODP) | kg CFC-11 eq | 1.26E-07 | 1.00E-10 | 2.58E-10 | 0.00E+00 | 7.09E-10 | 0.00E+00 | 6.74E-11 |
| Photochemical oxidation | kg C2H4 eq | 5.02E-04 | 3.04E-06 | 2.17E-05 | 0.00E+00 | 9.65E-06 | 0.00E+00 | 2.61E-06 |
| Acidification | kg SO2 eq | 9.46E-03 | 9.89E-05 | 6.31E-05 | 0.00E+00 | 2.22E-04 | 0.00E+00 | 3.06E-05 |
| Eutrophication | kg PO4--- eq | 2.54E-03 | 1.22E-05 | 1.82E-04 | 0.00E+00 | 5.02E-05 | 0.00E+00 | 5.74E-04 |

## 4.2. Life Cycle Inventory Results

Table 17 Life cycle inventory results-ArmaFlex AC Class 0 (1 m)

| Impact category | Unit | production | transport of product | installation | deconstruction | transport of waste | Waste processing | disposal |
|---|---|---|---|---|---|---|---|---|
| | | A1-A3 | A4 | A5 | C1 | C2 | C3 | C4 |
| $NRPR_M$ | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $NRPR_E$ | MJ | 1.57E+01 | 1.76E-01 | 1.63E-01 | 0.00E+00 | 2.23E-01 | 0.00E+00 | 3.41E-02 |
| $RPR_M$ | MJ | 3.07E-01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $RPR_E$ | MJ | 4.12E-01 | 1.88E-03 | 2.96E-03 | 0.00E+00 | 9.22E-04 | 0.00E+00 | 1.60E-03 |
| SM | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NRSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RE | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FW | $m^3$ | 2.91E-01 | 2.46E-03 | 2.78E-03 | 0.00E+00 | 1.02E-03 | 0.00E+00 | 1.62E-03 |
| HWD | kg | 1.71E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NHWD | kg | 1.05E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RWD | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| HLRW | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| ILLRW | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| CRU | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| MR | kg | 1.05E-02 | 0.00E+00 | 6.08E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.59E-01 |
| MER | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| EE | MJ, heating value ([Hi] lower heating value) per energy carrier | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Table 18 Life cycle inventory results-ArmaFlex AC Class 0 (1 $m^2$)

| Impact category | Unit | production | transport of product | installation | deconstruction | transport of waste | Waste processing | disposal |
|---|---|---|---|---|---|---|---|---|
| | | A1-A3 | A4 | A5 | C1 | C2 | C3 | C4 |
| $NRPR_M$ | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $NRPR_E$ | MJ | 8.48E+01 | 9.54E-01 | 8.82E-01 | 0.00E+00 | 1.21E+00 | 0.00E+00 | 1.84E-01 |
| $RPR_M$ | MJ | 1.66E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $RPR_E$ | MJ | 2.23E+00 | 1.02E-02 | 1.60E-02 | 0.00E+00 | 4.98E-03 | 0.00E+00 | 8.65E-03 |
| SM | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NRSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RE | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FW | m3 | 1.57E+00 | 1.33E-02 | 1.50E-02 | 0.00E+00 | 5.49E-03 | 0.00E+00 | 8.75E-03 |
| HWD | kg | 9.27E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NHWD | kg | 5.66E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RWD | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| HLRW | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| ILLRW | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| CRU | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| MR | kg | 5.66E-02 | 0.00E+00 | 3.29E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 8.57E-01 |
| MER | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| EE | MJ, heating value ([Hi] lower heating value) per energy carrier | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Table 19 Life cycle inventory results-AP/ArmaFlex (1 m)

| **Impact category** | **Unit** | **production** | **transport of product** | **installation** | **deconstruction** | **transport of waste** | **Waste processing** | **disposal** |
|---|---|---|---|---|---|---|---|---|
| | | **A1-A3** | **A4** | **A5** | **C1** | **C2** | **C3** | **C4** |
| $NRPR_M$ | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $NRPR_E$ | MJ | 1.19E+01 | 2.45E-02 | 1.24E-01 | 0.00E+00 | 1.70E-01 | 0.00E+00 | 1.87E-02 |
| $RPR_M$ | MJ | 2.43E-01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $RPR_E$ | MJ | 3.53E-01 | 2.54E-04 | 2.26E-03 | 0.00E+00 | 7.01E-04 | 0.00E+00 | 8.79E-04 |
| SM | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NRSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RE | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FW | m3 | 1.52E+00 | 3.39E-04 | 2.12E-03 | 0.00E+00 | 7.73E-04 | 0.00E+00 | 8.89E-04 |
| HWD | kg | 1.36E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NHWD | kg | 8.30E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RWD | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| HLRW | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ILLRW | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| CRU | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| MR | kg | 8.30E-03 | 0.00E+00 | 5.34E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.41E-01 |
| MER | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| EE | MJ, heating value ([Hi] lower heating value) per energy carrier | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Table 20 Life cycle inventory results-AP/ArmaFlex (1 $m^2$)

| **Impact category** | **Unit** | **production** | **transport of product** | **installation** | **deconstruction** | **transport of waste** | **Waste processing** | **disposal** |
|---|---|---|---|---|---|---|---|---|
| | | **A1-A3** | **A4** | **A5** | **C1** | **C2** | **C3** | **C4** |
| $NRPR_M$ | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $NRPR_E$ | MJ | 4.93E+01 | 1.01E-01 | 5.14E-01 | 0.00E+00 | 7.03E-01 | 0.00E+00 | 7.75E-02 |
| $RPR_M$ | MJ | 1.01E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $RPR_E$ | MJ | 1.46E+00 | 1.05E-03 | 9.34E-03 | 0.00E+00 | 2.90E-03 | 0.00E+00 | 3.64E-03 |
| SM | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NRSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RE | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FW | m3 | 6.31E+00 | 1.41E-03 | 8.76E-03 | 0.00E+00 | 3.20E-03 | 0.00E+00 | 3.68E-03 |
| HWD | kg | 5.63E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NHWD | kg | 3.44E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RWD | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| HLRW | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| ILLRW | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| CRU | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| MR | kg | 3.44E-02 | 0.00E+00 | 2.21E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 5.85E-01 |
| MER | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| EE | MJ, heating value ([Hi] lower heating value) per energy carrier | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Table 21 Carbon emissions and uptake (1 $m^2$)

| Parameter | units | ArmaFlex AC Class 0 | AP/ArmaFlex |
|---|---|---|---|
| BCRP | kg $CO_2$ | 0 | 0 |
| BCEP | kg $CO_2$ | 0 | 0 |
| BCRK | kg $CO_2$ | 1.37E-01 | 8.29E-02 |
| BCEK | kg $CO_2$ | 5.21E-02 | 2.28E-02 |
| BCEW | kg $CO_2$ | N/A | N/A |
| CCE | kg $CO_2$ | N/A | N/A |
| CCR | kg $CO_2$ | N/A | N/A |
| CWNR | kg $CO_2$ | N/A | N/A |

Table 22 Carbon emissions and uptake (1 m)

| Parameter | units | ArmaFlex AC Class 0 | AP/ArmaFlex |
|---|---|---|---|
| BCRP | kg $CO_2$ | 0 | 0 |
| BCEP | kg $CO_2$ | 0 | 0 |
| BCRK | kg $CO_2$ | 2.53-02 | 2.00E-02 |
| BCEK | kg $CO_2$ | 9.64E-03 | 5.52E-03 |
| BCEW | kg $CO_2$ | N/A | N/A |
| CCE | kg $CO_2$ | N/A | N/A |
| CCR | kg $CO_2$ | N/A | N/A |
| CWNR | kg $CO_2$ | N/A | N/A |

## 5. LCA Interpretation

The stage contribution analysis of the two insulation products on various impact categories reveals that production, transport of product and waste are the main contributions to environment impact categories.

The process contribution analysis reveals that raw material supply contributes to most of the environmental impacts.

Sensitivity analysis shows that the changes in assumptions such as substituted raw materials and transportation distance and installation inputs can lead to certain fluctuation of the final LCA results, hence it is recommended to continuously update the model to get up-to-date results, in case the assumption or process parameters will be changed in the future, or better data would be provided, especially regarding the substituted material where the

background data for the raw material is not available.

## 6. Additional Environmental Information

### 6.1. Environment and Health During Manufacturing

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.

### 6.2. Environment and Health During Installation

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

### 6.3. Environmental Activities and Certifications

Armacell insulation products are certified with GREENGUARD Gold, manufactured without CFCs, HFCs, HCFCs, PBDEs, or Formaldehyde and made with EPA registered Microban® antimicrobial product protection. Besides, all Armacell facilities are ISO 9001:2008 certified.

### 6.4. Further Information

Additional information about Armacell's products can be found on the website:https://www.armacell.com/.

## 7. Project Report and Supporting Documentation

Since the amount of input and output has a linear relationship with the total output of production, i.e. the more the product manufactured, the more raw material, energy, water and natural gas will be consumed. For simplification in this analysis, the annual total input and output flow are distributed among the different product specifications using a production weight- ratio based distribution model, due to lack of monitoring record results for different brands of product, the distribution of flow among the various specifications is based on calculations. As the production of insulation products are counted in volume, the distribution model are also calculated in volume and converted to mass based on the density of different product brands.

## 8. References


- 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
- ISO 21930:2017 - Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services
- UL Environment Part A: Life Cycle Assessment Calculation Rules and Report Requirements v.4.0 March 2022
- UL Environment Part B: Insulated Metal Panels, Metal Composite Panels, and Metal Cladding v.1.0 September 2019
- UL General Program Instructions v.2.7 March 2022
- SimaPro - LCA Computer Software -http://www.pre-sustainability.com/
- Report - LCA Report for Armaflex insulation materials (ArmaFlex AC Class 0,AP/ArmaFlex) by Fangyan Xu Ecovane Environmental Co., Ltd, May 9, 2024