Environmental Product Declaration

Mineral Wool Board

NORTH AMERICAN INSULATION MANUFACTURERS ASSOCIATION

Mineral wool insulation products: saving energy, reducing pollution, and contributing to a sustainable environment.

NAIMA
North American Insulation Manufacturers Association

The North American Insulation Manufacturers Association (NAIMA) is the association for North American manufacturers of fiber glass, rock wool, and slag wool insulation products. The Association seeks to promote energy efficiency and environmental preservation through the use of fiber glass, rock wool, and slag wool insulation, and to encourage the safe production and use of these materials. NAIMA advocates for improved energy efficiency in homes and buildings as the quickest and most cost-effective way to reduce energy use and lower greenhouse gas emissions.

Insulation saves 12 times as much energy per pound in its first year of use as the energy used to produce it. In fact, insulation in place in U.S. buildings reduces the amount of carbon dioxide emissions by 780 million tons per year.

UL CERTIFIED
ENVIRONMENTAL PRODUCT DECLARATION
UL.COM/EPD

CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION UL.COM/EPD

LIGHT AND HEAVY DENSITY MINERAL WOOL BOARD

According to ISO 14025, EN 15804, and ISO21930:2017

EPD PROGRAM AND PROGRAM OPERATOR NAME, ADDRESS, LOGO, AND WEBSITE	UL Environment 333 Pfingsten Road Northbrook, IL 60611	https://www.ul.com/ https://spot.ul.com/
GENERAL PROGRAM INSTRUCTIONS AND VERSION NUMBER	General Program Instructions v.2.4 July 2018	
MANUFACTURER NAME AND ADDRESS	North American Insulation Manufacturers Association 11 Canal Center Plaza, Suite 103, Alexandria, VA 22314	
DECLARATION NUMBER	4788703029.101.1	
DECLARED PRODUCT & FUNCTIONAL UNIT OR DECLARED UNIT	Light and heavy density mineral wool board, 1 m^2 R_{SI}-1	
REFERENCE PCR AND VERSION NUMBER	Part B: Building Envelope Thermal Insulation EPD Requirements, UL 10010-1 April 2018, v.2.0	
DESCRIPTION OF PRODUCT APPLICATION/USE	Building envelope thermal insulation; ceiling tile production	
PRODUCT RSL DESCRIPTION (IF APPL.)	N/A	
MARKETS OF APPLICABILITY	North America	
DATE OF ISSUE	November 7, 2018	
PERIOD OF VALIDITY	5 Years	
EPD TYPE	Industry-average	
RANGE OF DATASET VARIABILITY	Industry-average only	
EPD SCOPE	Cradle to installation with end-of-life	
YEAR(S) OF REPORTED PRIMARY DATA	2017	
LCA SOFTWARE & VERSION NUMBER	GaBi ts v8.7	
LCI DATABASE(S) & VERSION NUMBER	GaBi 2018 (service pack 36)	
LCIA METHODOLOGY & VERSION NUMBER	TRACI 2.1	

This PCR Review was conducted by:	UL Environment PCR Review Panel epd@ulenvironment.com
This declaration was independently verified in accordance with ISO 14025: 2006. ☐ INTERNAL ☒ EXTERNAL	Grant R. Martin Grant R. Martin, UL Environment
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	Thomas Gloria Thomas P. Gloria, Industrial Ecology Consultants

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

The North American Insulation Manufacturers Association (NAIMA) is the association for North American manufacturers of fiberglass and mineral wool (i.e., rock wool and slag wool) insulation products. NAIMA promotes energy efficiency and environmental preservation through the use of fiberglass and mineral wool insulation, and encourages the safe production and use of these materials.

NAIMA members who produce mineral wool include:

Aislantes Minerales, S.A. de C.V.
D.F. Mexico
www.rolan.com

American Rockwool Manufacturing, LLC
Bell County, TX
www.americanrockwool.com

Armstrong World Industries
Lancaster, PA
www.armstrong.com

Industrial Insulation Group, LLC
Brunswick, GA
www.iig-llc.com

ROCKWOOL Group
Milton, Ontario
www.rockwool.com

Rock Wool Manufacturing Co.
Leeds, AL
www.deltainsulation.com

Thermafiber, Inc.
Wabash, IN
www.thermafiber.com

USG Interiors, Inc.
Chicago, IL
www.usg.com

1.2. Product Description

Product Identification

Mineral wool insulation products come in myriad forms, shapes, and sizes, including: board; batt; loose fill; spray-applied; and pipe insulation. Whatever its form, mineral wool insulation resists mold, fungi, and bacteria growth because the material is inorganic. These products also offer enhanced protection against damaging moisture infiltration that can rob insulation of R-value. Further, mineral wool insulation is not corrosive and contains no chemicals that can degrade pipes and wires.

Mineral board materials are used in: curtain walls, commercial roofs, basement walls, floors over unheated or open spaces (e.g., garages or porches), and other building envelope applications. Board insulation is extensively employed in industrial processes. Further, the greater density of mineral wool insulation allows the materials to achieve higher R-values and, thus, insulating power. This translates into increased year-round comfort and significant energy savings.

In partitions, floors, and ceilings, the fibrous structure and high density of mineral wool insulation offer sound absorption properties, making these products an excellent part of overall wall systems designed to reduce sound transmission (Crane).

Product Specification

Mineral wool board is an effective form of insulation. Relevant standards are shown in section 1.5.

Flow Diagram

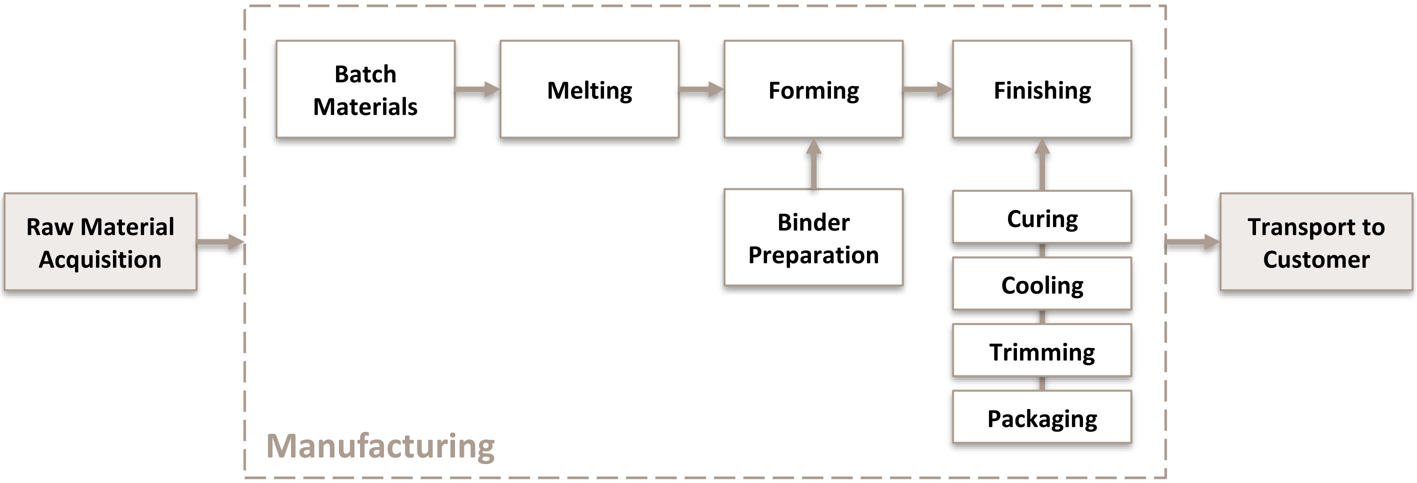

Figure 1: Flow diagram for manufacturing mineral wool board

Product Average

This EPD is intended to represent an industry average for mineral wool board. The vertical average is calculated based on the mass of product manufactured by NAIMA member companies. NAIMA represents the majority of the North American rock and slag wool industry. Use of this EPD is limited to NAIMA member companies.

1.3. Application

The fibrous composition of mineral wool insulation provides a flexibility and versatility not found in most other insulations. Mineral wool insulation comes in a wide variety of forms, shapes and sizes, including board, batt, loose-fill, spray-applied, and pipe insulation for many common and specialized applications. Applications include:

- Residential
  - Thermal (walls and attics)
  - Foundation drainage systems
  - Acoustical (walls and ceilings)
- Commercial
  - Thermal (walls and roofs)
  - Fire stopping and containment
  - Acoustical applications
  - Acoustical ceiling tiles
- Industrial
  - Thermal (ovens, boilers, kilns, etc.)
  - Fire stopping and containment
  - Acoustical (sound absorbers)
  - Emissions control
  - Pipe/mechanical systems
  - Fillers

1.4. Declaration of Methodological Framework

This EPD is declared under a “cradle-to-installation with end-of-life” system boundary. As such, it includes life cycle stages A1-A5 and C1-C4.

Per the product category rules (UL Environment, 2018), the assessment was conducted using a building service life of 75 years. Allocation of manufacturing material and energy inputs was done on a mass-basis. Allocation of transportation was based on mass while taking into account the utilization rate.

For recycled content and disposal at end-of-life, system boundaries were drawn consistent with the cut-off allocation approach. Additional details can be found in section 2.8. No known flows are deliberately excluded from this EPD.

1.5. Technical Requirements

The technical specifications apply to products considered in this EPD:

- ASTM C553 – Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
- ASTM C612 – Standard Specification for Mineral Fiber Bloack and Board Thermal Insulation
- ASTM C726 – Standard Specification for Mineral Wool Roof Insulation Board

Additionally, the the following fire-related standards and test methods apply:

- NFPA 220 – Standard on Types of Building Construction
- ASTM E136 – Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C
- ASTM E84 – Standard Test Method for Surface Burning Characteristics of Building Materials
- NFPA 101 – Life Safety Code

1.6. Properties of Declared Product as Delivered

Mineral wool board is produced in a variety of thicknesses from 1 inch to 7 inches (25 to 178 mm) and at densities from 2.5 to 8 PCF (pounds per cubic foot) (48 to 128 kg/m^3). Board below 4.3 PCF is generally considered light density and board above 4.4 PCF is generally considered heavy density. Thermal conductivity varies according to board density and thickness. Additionally, density, thermal conductivity, and thickness of the insulation will depend on product configuration and application.

1.7. Material Composition

Mineral wool insulation includes both rock wool and slag wool insulation, which are produced in the same way and comprised of essentially the same raw materials but in different proportions. Manufacturers use a mechanized process to spin a molten composition of rock and slag into high-temperature-resistant fibers. The similar properties of both insulation types lead to fairly similar performance attributes. The major difference is in the specific volumes of the various raw materials used to make each product.

Rock wool insulation is composed principally of fibers manufactured from a combination of aluminosilicate rock (usually basalt), blast furnace slag, and limestone or dolomite. Slag is a byproduct from steel production that would otherwise be landfilled. Binders may or may not be used, depending on the product. Typically, rock wool insulation is comprised of a minimum of 70% – 75% natural rock. The remaining volume of raw material is blast furnace slag.

Slag wool insulation is composed principally of fibers manufactured by melting the primary component, blast furnace slag, in combination with some natural rock. Binders may be used depending on the product. Typically, slag wool insulation uses approximately 70% blast furnace slag, with the remaining volume of raw materials being natural rock.

Due to the similarities between the two types of mineral wool, an aggregate view will be used throughout this document that combines both slag and rock wools. Table 1 provides the average material content for both board products, although among the manufacturers, slag content can vary from 0% to 90%.

Table 1: Mineral wool board material content

COMPONENT	LIGHT DENSITY BOARD [WT. %]	HEAVY DENSITY BOARD [WT. %]
Mineral wool batch		
Slag	62%	64%
Basalt	13%	5.1%
Feldspar	5.8%	12%
Trap rock	7.5%	7.1%
Dolomite	3.3%	1.2%
Granite	1.6%	0.21%
Limestone	1.1%	0.42%
Iron ore	0.92%	5.2%
Binder		
Phenolic resin	3.0%	3.2%
Urea	1.5%	1.8%
Other binder materials	0.14%	0.12%

1.8. Manufacturing

This EPD covers light density and heavy density mineral wool board produced by manufacturers in the United States and Mexico. Four facilities located in Alabama and Indiana (United States), and Mexico were considered in the analysis. These facilities were chosen as their respective manufacturers sell board on the market and were willing to provide data.

The life cycles of the light and heavy density mineral wool board products begin with raw material extraction and processing. These batch materials are melted and combined with binder materials, after which they are formed into boards with the requisite density. After curing and cooling periods they are cut into the desired shape and packaged for transport to the customer (see flow diagram in Figure 1).

1.9. Packaging

Mineral wool is typically packaged using a combination of with plastic wrap, plastic banding, and cardboard / corrugate. Packaging materials are not assumed to be reused. Since no primary data are available, the disposal assumptions provided in Part A (UL Environment, 2018) are used.

1.10. Transportation

Average transportation distances via truck and rail are included for the transport of the raw materials to production facilities. Transport of the finished product 500 miles via truck to the construction site is also accounted for, along with the transport of construction wastes and the deconstructed product at end-of-life to disposal facilities (20 miles via truck). Distribution of the finished product is assumed to be volume-limited rather than mass-limited with a utilization rate of 23% of mass capacity for light density board and 73% of mass capacity for heavy density board. Additional information is provided in Table 4.

1.11. Product Installation

Mineral wool products are made for easy handling and installation. Wherever insulation is installed in a building, it is very important that it fit tightly on all sides. Insulation should be installed just before the interior finish is applied.

It is difficult to describe every situation that will be encountered by the insulation installer. In general, however, the installer should be guided by the need to reduce heat flow around or through obstructions and to protect mechanical systems.

It is recommended that the installer follow the criteria developed by the Residential Energy Services Network (RESNET).

Packaging disposal is included as part of the installation module. No product loss is assumed since any extra product can be used in subsequent jobs. For additional information, please refer to Table 5.

1.12. Use

Once installed, insulation does not directly consume energy, and requires no maintenance. There are no parts to repair or refurbish. Any reduction in building operational energy consumption associated with insulation use need to be considered on the level of the individual building and are considered outside the scope of the LCA.

1.13. Reference Service Life and Estimated Building Service Life

Mineral wool insulation is assumed to have a reference service life of 75 years, equal to that of the building.

1.14. Reuse, Recycling, and Energy Recovery

Mineral wool loose fill is typically not reused or recycled following its removal from a building. Although recycling is feasible, there are minimal recycling programs and infrastructure; therefore, current practice is to send the waste to a landfill. Thus, reuse, recycling, and energy recovery are not applicable for this product.

1.15. Disposal

At the end-of-life, insulation is removed from the deconstructed building. The waste is then transported 20 miles and disposed in a landfill per PCR requirements (UL Environment, 2018) (see Table 3). Landfill and incineration emissions from paper, plastic, and wood packaging are allocated to installation (module A5).

2. Life Cycle Assessment Background Information

2.1. Functional or Declared Unit

Per the product category rules, the functional unit for this analysis is 1 m^2 of insulation material with a thickness that gives an average thermal resistance R_{SI} = 1 m^2K/W and a building service life of 75 years. In imperial units, the R_{SI} value is equivalent to R_{US} = 5.68.

Table 2: Functional unit

NAME	LIGHT DENSITY BOARD	HEAVY DENSITY BOARD	UNIT
Functional unit	1 m^2 of insulation material with a thickness that gives an average thermal resistance R_{SI} = 1 m^2K/W		
Mass	1.72	4.20	kg
Thickness to achieve functional unit	39	34	mm

2.2. System Boundary

A cradle-to-installation with end-of-life system boundary was used for the analysis. Within these boundaries the following stages were included:

- Product stage: modules A1 to A3
- Construction stage: modules A4 and A5
- End-of-life stage: modules C1 to C4

Each module includes provision of all relevant materials, products and energy. Impacts and aspects related to wastage (i.e. production, transport and waste processing and end-of-life stage of lost waste products and materials) are considered in the module in which the wastage occurs. Building operational energy and water use are considered outside of this study's scope: any impact the use of insulation may have on a building's energy consumption is not calculated or incorporated into the analysis.

The end-of-life stage modules C1 and C3 are declared as having zero impact as deconstruction is done manually and the insulation is not recycled. Consequently, there are no direct emissions associated with these modules.

Per the PCR, capital goods and infrastructure flows are assumed to not significantly affect LCA results or conclusions and thus excluded from the analysis.

2.3. Estimates and Assumptions

The analysis uses the following assumptions:

- If inbound transportation distances were not provided for materials used in manufacturing, a default assumption of 500 miles (800 km) transport via truck was applied in the model.
- Installation is done by hand and is assumed to have a 3% scrap rate. Four 1 ½-inch fasteners per square meter are assumed to be necessary for installation.
- Since primary data were not available to describe end-of-life treatment, the default values specified by the PCR Part A (UL Environment, 2018) were applied (Table 3).
- Mineral wool insulation is assumed to last the lifespan of the building and is only removed upon building demolition. Since the PCR states that the building has a 75-year reference service life, the insulation is assumed to have the same reference service life.

Table 3. Default end-of-life assumptions from the PCR

COMPONENT	RECYCLED	LANDFILLED	INCINERATED
Product	0%	100%	0%
Paper packaging	75%	20%	5%
Plastic packaging	15%	68%	17%

2.4. Cut-off Criteria

For the processes within the system boundary, all available energy and material flow data have been included in the model. In cases where no matching life cycle inventories are available to represent a flow, proxy data have been applied based on conservative assumptions regarding environmental impacts. Cut-off criteria, however, were applied to exclude capital goods and infrastructure as these are assumed to not significantly affect LCA results nor conclusions.

2.5. Data Sources

The LCA model was created using the GaBi ts Software system for life cycle engineering, developed by thinkstep AG (thinkstep, 2018). Background life cycle inventory data for raw materials and processes were obtained from the GaBi 2018 database (service pack 36). Primary manufacturing data were provided by NAIMA members.

2.6. Data Quality

A variety of tests and checks were performed throughout the project to ensure high quality of the completed LCA. Checks included a review of project-specific LCA models as well as the background data used.

Geographical Coverage

In order to satisfy cut-off criteria, proxy datasets were used as needed for raw material inputs to address lack of data for a specific material or for a specific geographical region. These proxy datasets were chosen for their representativeness of the actual product. Additionally, European data or global data were used when North American data (for raw materials sourced in the US) were not available.

Temporal Coverage

Foreground data for each manufacturer represent a continuous 12-months period taking place sometime over the previous five years (in line with PCR requirements). The majority of background datasets are based on data from the last 4 years (since 2014).

Technological Coverage

The primary data represent production of the products under evaluation. Secondary data were chosen to be specific to the technologies in question (or appropriate proxy data used where necessary).

Completeness

Foreground processes were checked for mass balance and completeness of the emissions inventory. No data were knowingly omitted.

2.7. Period under Review

Primary data collected represent production during the last five years (in line with PCR requirements), although the majority of the data are from the 2017 calendar year. This analysis is intended to represent production in 2017.

2.8. Allocation

Allocation of manufacturing material and energy inputs was done on a mass-basis. Allocation of transportation was based on mass while taking into account the utilization rate.

For recycled content and disposal at end-of-life, system boundaries were drawn consistent with the cut-off allocation approach. Slag, which is used as a raw material in mineral wool loose fill production, is assumed to enter the system burden-free in that burden associated with the production of the slag itself is not allocated to the insulation life cycle. Likewise, the system boundary was drawn to include landfilling of mineral wool at end-of-life (following the polluter-pays principle) but exclude any avoided burdens from material or energy recovery.

2.9. Comparability (Optional)

No comparisons or benchmarking is 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. Caution should be used when attempting to compare EPD results.

3. Life Cycle Assessment Scenarios

Table 4. Transport to the building site (A4)

NAME	LIGHT BOARD	HEAVY BOARD	UNIT
Fuel type	Diesel	Diesel	
Liters of fuel	32	35	L/100km
Vehicle type	Truck	Truck	
Transport distance	800	800	km
Truck capacity utilization (including empty runs, mass based)	17	55	%
Gross density of products transported	44.1	122	kg/m^3
Weight of products transported (if gross density not reported)	N/A	N/A	kg
Volume of products transported (if gross density not reported)	N/A	N/A	m^3
Capacity utilization volume factor (factor: =1 or <1 or ≥ 1 for compressed or nested packaging products)	1	1	-

Table 5. Installation into the building (A5)

Name	Light Board	Heavy Board	Unit
Ancillary materials	0.021	0.021	kg
Net freshwater consumption specified by water source and fate (amount evaporated, amount disposed to sewer)	0	0	m^3
Other resources	0	0	kg
Electricity consumption	0	0	kWh
Other energy carriers	0	0	MJ
Product loss per functional unit	0.053	0.13	kg
Waste materials at the construction site before waste processing, generated by product installation	0.072	0.15	kg
Output materials resulting from on-site waste processing			
Recycling	0.0032	0.0044	kg
Incineration	0.0033	0.0041	kg
Landfill	0.066	0.15	kg
Biogenic carbon contained in packaging	8.5E-04	2.0E-03	kg CO_2
Direct emissions to ambient air, soil and water	0	0	kg
VOC content	0	0	μg/m^3

Table 6. Reference Service Life

Name	Light Board	Heavy Board	Unit
RSL	75	75	years

Table 7. End of life (C1-C4)

Name		Light Board	Heavy Board	Unit
Assumptions for scenario development (description of deconstruction, collection, recovery, disposal method and transportation)				
Collection process (specified by type)	Collected separately	1.72	4.20	kg
	Collected with mixed construction waste	0	0	kg
Recovery (specified by type)	Reuse	0	0	kg
	Recycling	0	0	kg
	Landfill	1.72	4.20	kg
	Incineration	0	0	kg
	Incineration with energy recovery	0	0	kg
	Energy conversion efficiency rate	0	0	
Disposal (specified by type)	Product or material for final deposition	1.72	4.20	kg
Removals of biogenic carbon (excluding packaging)		0	0	kg CO_2

4. Life Cycle Assessment Results

Table 8. Description of the system boundary modules. X = included in EPD scope; MND = module not declared (i.e., excluded from EPD scope)

	PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY
	A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
	Raw material supply	Transport	Manufacturing	Transport from gate to site	Assembly/Install	Use	Maintenance	Repair	Replacement	Refurbishment	Building Operational Energy Use During Product Use	Building Operational Water Use During Product Use	Deconstruction	Transport	Waste processing	Disposal	Reuse, Recovery, Recycling Potential
EPD Type	X	X	X	X	X	MND	MND	MND	MND	MND	MND	MND	X	X	X	X	MND

Impact assessment and other results are shown for a cradle-to-installation with end-of-life system boundary. Modules C1 and C3 are not associated with any impact and are therefore declared as zero.

Biogenic carbon is not reported in global warming potential (GWP) as mineral wool products do not typically contain bio-based materials. As such, carbon emissions and removals are not declared.

4.1. Life Cycle Impact Assessment Results: Light Density Board

Table 9. North American Impact Assessment Results: Light Density Board

TRACI v2.1	A1-A3	A4	A5	C2	C4
Global warming potential, GWP 100 [kg CO_2 eq]	3.33E+00	3.92E-01	1.99E-01	4.24E-03	7.78E-02
Ozone depletion potential, ODP [kg CFC-11 eq]	3.21E-11	1.35E-14	1.02E-12	1.46E-16	1.41E-14
Acidification potential, AP [kg SO_2 eq]	1.09E-02	2.16E-03	6.13E-04	1.99E-05	3.53E-04
Eutrophication potential, EP [kg N eq]	2.93E-04	1.70E-04	3.47E-05	1.62E-06	1.79E-05
Photochemical ozone creation potential, POCP [kg O_3 eq]	9.01E-02	7.22E-02	7.98E-03	6.57E-04	7.01E-03
Abiotic depletion potential (fossil), ADP_{fossil} [MJ, surplus]	2.99E+00	7.46E-01	1.48E-01	8.07E-03	1.53E-01

4.2. Life Cycle Inventory Results: Light Density Board

Table 10. Resource Use: Light Density Board

PARAMETER	A1-A3	A4	A5	C2	C4
Renewable primary resources used as energy carrier (fuel) RPR_E [MJ, LHV]	1.56E+00	1.38E-01	1.57E-01	1.50E-03	8.64E-02
Renewable primary resources with energy content used as material, RPR_M [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable primary resources used as energy carrier (fuel), $NRPR_E$ [MJ, LHV]	3.95E+01	5.60E+00	2.17E+00	6.06E-02	1.22E+00
Non-renewable primary resources with energy content used as material, $NRPR_M$ [MJ, LHV]	3.99E-01	0.00E+00	1.23E-02	0.00E+00	0.00E+00
Secondary materials, SM [kg]	1.66E+00	0.00E+00	5.13E-02	0.00E+00	0.00E+00
Renewable secondary fuels, RSF [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable secondary fuels, NRSF [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Recovered energy, RE [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fresh water, FW [m^3]	9.39E-03	6.74E-04	4.37E-04	7.29E-06	1.48E-04

Table 11. Output Flows and Waste Categories: Light Density Board

PARAMETER	A1-A3	A4	A5	C2	C4
Hazardous waste disposed, HWD [kg]	8.75E-08	4.35E-08	4.76E-09	4.71E-10	4.22E-09
Non-hazardous waste disposed, NHWD [kg]	7.74E-01	2.10E-04	9.45E-02	2.27E-06	1.74E+00
High-level radioactive waste, HLRW [kg]	1.50E-06	1.48E-08	7.54E-08	1.61E-10	1.59E-08
Intermediate- & low-level radioactive waste, ILLRW [kg]	4.07E-05	4.01E-07	1.93E-06	4.34E-09	3.78E-07
Components for reuse, CRU [kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for recycling, MR [kg]	0.00E+00	0.00E+00	3.19E-03	0.00E+00	0.00E+00
Materials for energy recovery, MER [kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Exported energy, electrical EEE [MJ, LHV]	0.00E+00	0.00E+00	1.72E-02	0.00E+00	0.00E+00
Exported energy, thermal EET [MJ, LHV]	0.00E+00	0.00E+00	6.89E-03	0.00E+00	0.00E+00

4.3. Life Cycle Impact Assessment Results: Heavy Density Board

Table 12. North American Impact Assessment Results: Heavy Density Board

TRACI v2.1	A1-A3	A4	A5	C2	C4
Global warming potential, GWP 100 [kg CO_2 eq]	8.16E+00	3.33E-01	3.51E-01	1.03E-02	1.89E-01
Ozone depletion potential, ODP [kg CFC-11 eq]	7.48E-11	1.15E-14	2.34E-12	3.56E-16	3.42E-14
Acidification potential, AP [kg SO_2 eq]	1.89E-02	1.66E-03	8.48E-04	4.83E-05	8.58E-04
Eutrophication potential, EP [kg N eq]	7.64E-04	1.33E-04	4.56E-05	3.93E-06	4.35E-05
Photochemical ozone creation potential, POCP [kg O_3 eq]	2.00E-01	5.51E-02	1.11E-02	1.60E-03	1.70E-02
Abiotic depletion potential (fossil), ADP_{fossil} [MJ, surplus]	7.65E+00	6.34E-01	2.96E-01	1.96E-02	3.72E-01

4.4. Life Cycle Inventory Results: Heavy Density Board

Table 13. Resource Use: Heavy Density Board

PARAMETER	A1-A3	A4	A5	C2	C4
Renewable primary resources used as energy carrier (fuel) RPR_E [MJ, LHV]	3.77E+00	1.18E-01	2.29E-01	3.64E-03	2.10E-01
Renewable primary resources with energy content used as material, RPR_M [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable primary resources used as energy carrier (fuel), $NRPR_E$ [MJ, LHV]	9.90E+01	4.75E+00	4.04E+00	1.47E-01	2.97E+00
Non-renewable primary resources with energy content used as material, $NRPR_M$ [MJ, LHV]	1.24E+00	0.00E+00	3.85E-02	0.00E+00	0.00E+00
Secondary materials, SM [kg]	4.33E+00	0.00E+00	1.34E-01	0.00E+00	0.00E+00
Renewable secondary fuels, RSF [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable secondary fuels, NRSF [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Recovered energy, RE [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fresh water, FW [m^3]	2.28E-02	5.72E-04	8.57E-04	1.77E-05	3.60E-04

Table 14. Output Flows and Waste Categories: Heavy Density Board

PARAMETER	A1-A3	A4	A5	C2	C4
Hazardous waste disposed, HWD [kg]	2.12E-07	3.70E-08	8.61E-09	1.14E-09	1.02E-08
Non-hazardous waste disposed, NHWD [kg]	2.38E+00	1.79E-04	2.23E-01	5.53E-06	4.23E+00
High-level radioactive waste, HLRW [kg]	3.93E-06	1.26E-08	1.51E-07	3.90E-10	3.86E-08
Intermediate- & low-level radioactive waste, ILLRW [kg]	1.07E-04	3.40E-07	3.98E-06	1.05E-08	9.18E-07
Components for reuse, CRU [kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for recycling, MR [kg]	0.00E+00	0.00E+00	4.37E-03	0.00E+00	0.00E+00
Materials for energy recovery, MER [kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Exported energy, electrical EEE [MJ, LHV]	0.00E+00	0.00E+00	2.16E-02	0.00E+00	0.00E+00
Exported energy, thermal EET [MJ, LHV]	0.00E+00	0.00E+00	8.66E-03	0.00E+00	0.00E+00

4.5. Scaling to Other R-values

Environmental performance results are presented per functional unit, defined as 1 m^2 of R_{SI} = 1 m^2K/W insulation. In the US, insulation is typically purchased based on board thickness and R-value stated in units of $ft^2 \cdot °F \cdot hr/Btu$. Environmental impacts per square meter of these alternative R-values can be calculated by multiplying the above results by scaling factors presented in Table 15 for select board thicknesses and a range of board densities.

Table 15. Scaling Factors to Other R-values

Board Thickness [in]	Customary US R-value	Scaling Factor per 1 m^2 of $R_{SI} = 1$
Light Density Board		
3-inches	R-11.1 to R-12.8	1.8 to 2.8
5-inches	R-18.5 to R-21.4	3.0 to 4.7
7-inches	R-25.9 to R-30	4.1 to 6.6
Heavy Density Board		
3-inches	R-10.3 to R12.5	0.87 to 2.3
5-inches	R-17.4 to R-20.8	1.4 to 3.9

$$\text{Board impact per } m^2 \text{ (R-xx)} = \text{Impact scaling factor (R-xx)} \times \text{Boardl impact per } m^2 \ (R_{SI} = 1)$$

5. LCA Interpretation

The manufacturing stage dominates the majority of impact categories due to the energy required by the melter and finishing stages. Outbound transport accounts for relevant contributions to the eutrophication potential and smog formation potential impact categories. For other impact categories, outbound transport is a minor contributor.

Installation accounts for a small fraction of overall life cycle impact given that minimal resources are required to install board. There is no impact associated with the use stage. While insulation can influence building energy performance, this aspect is outside the scope of this study. Additionally, it is assumed that insulation does not require any maintenance to achieve its reference service life, which is modeled as being equal to that of the building (i.e., 75 years). No replacements are necessary; therefore, results represent the production of one (1) square meter of insulation at a thickness defined by the PCR functional unit.

At end-of-life, insulation is removed from the building and landfilled. For both products, waste was dominated by the end-of-life disposal of the product. Non-hazardous waste also accounts for waste generated during manufacturing and installation.

6. Additional Environmental Information

6.1. Mandatory Environmental Information

Mineral wool board contains formaldehyde as an ingredient to its binder. Formaldehyde is classified as hazardous waste under the Resource Conservation and Recovery Act (RCRA) (EPA, n.d.). Release of substances from mineral wool to air, soil, or water is not a concern (US DHHS, 2004).

6.2. Environment and Health During Manufacturing

The NAIMA Product Stewardship Program's work practices apply to the manufacture, fabrication, installation, removal, and other work settings where workers are subject to exposures to mineral wool fibers. The Product Stewardship

Program commits manufacturers to use product design, engineering controls, work practices, respiratory protection or a combination of any or all of these measures to bring fiber exposures to the voluntary one fiber per cubic centimeter permissible exposure limit (1 f/cc PEL).

NAIMA has established an exposure database (Marchant, et al., 2002) (Marchant, et al., 2009) containing existing information about exposure levels categorized by product type and specific work task. The database establishes that manufacturing exposures are well below the voluntary permissible exposure limit (PEL) of 1 f/cc.

6.3. Building Use Stage Benefits

Sustainable insulation requires no additional energy or maintenance in order to perform during the life of service. Mineral wool insulation is effective in helping reduce heat flow, reduce unwanted noise, and control moisture.

6.4. Environment and Health During Installation

The NAIMA Product Stewardship Program's work practices apply to the installation as well as manufacturing and other occupational settings where workers are subject to exposures to mineral wool fibers. The Product Stewardship Program specifies comprehensive work practices for those working with mineral wool fibers, including recommendations for cost effective engineering controls (when applicable), proper respirator use, use of protective clothing, and work place guidelines. In locations that require power sawing, routing, sanding, or grinding, or employ other operations that lead to dusty conditions, local exhaust ventilation should be used.

NAIMA has established an exposure database (Marchant, et al., 2002) (Marchant, et al., 2009) containing existing information about exposure levels categorized by product type and specific work task.

According to the "Toxicological Profile for Synthetic Vitreous Fibers" (US DHHS, 2004):

> Very low levels of synthetic vitreous fibers can be found in virtually all homes, buildings, and outside air, but there is little concern regarding these low levels… As long as the [SVF] materials are not physically disturbed or breaking down, the levels of synthetic vitreous fibers in the air should be very low.
>
> The overwhelming majority of human exposure to synthetic vitreous fibers occurs as occupational exposure through inhalation and dermal contact. Occupational exposure is estimated to be several orders of magnitude greater than environmental exposure.
>
> The exposure of the general population (non-occupational exposure) to synthetic vitreous fibers in both indoor and outdoor air is low… Furthermore, it has been shown that the airborne levels of synthetic vitreous fibers attenuate rapidly following installation.

6.5. Extraordinary Effects

Fire

The performance of building materials in a fire is a key factor in protecting the occupants of the building and allowing them to escape safely. Mineral wool insulation is naturally non-combustible and remains this way for the life of the product without the addition of harsh and potentially dangerous chemical fire retardants. The insulation can resist temperatures in excess of 2,000°F. Because these products have a high melting temperature, they can be used in a wide variety of applications that call for these unique properties.

Due to these properties, mineral wool insulation can be used as passive fire protection in many buildings. Manufacturers of these products encourage a balanced design, which includes a combination of active, detective, and passive fire protection in building codes to ensure the safety of building occupants.

These products should meet NFPA 220 and ASTM E136 standards and test methods and are Class A product tested per ASTM E84 and NFPA 101.

6.6. Health Impacts

NAIMA and its member companies are committed to ensuring that mineral wool products can be safely manufactured, installed, and used. NAIMA member companies have funded tens of millions of dollars of research at leading independent laboratories and universities in the United States and abroad. The weight of the scientific research shows no association between exposure to mineral wool fibers and respiratory disease or cancer in humans.

In October 2001, an international expert review by the International Agency for Research on Cancer (IARC) (IARC, 2001) re-evaluated the 1988 IARC assessment of glass fibers and removed glass and mineral wool fibers from its list of substances “possibly carcinogenic to humans.” All fiberglass and mineral wools that are commonly used for thermal and acoustical insulation are now considered not classifiable as to carcinogenicity to humans (Group 3). IARC noted specifically:

> Epidemiologic studies published during the 15 years since the previous IARC Monographs review of these fibers in 1988 provide no evidence of increased risks of lung cancer or mesothelioma (cancer of the lining of the body cavities) from occupational exposures during manufacture of these materials, and inadequate evidence overall of any cancer risk.

The IARC downgrade is consistent with the conclusion reached by the U.S. National Academy of Sciences, which in 2000 found “no significant association between fiber exposure and lung cancer”.

Scientific evidence demonstrates that mineral wool is safe to manufacture, install, and use when recommended work practices are followed. Following these work practices will help to reduce irritation.[1]

7. References

Crane, A. (n.d.). Specifying Rock & Slag Wool Insulation. *Construction Canada*.

EPA. (n.d.). *Resource Conservation and Recovery Act (RCRA) Laws and Regulations*. Retrieved Oct 16, 2018, from Environmental Protection Agency: https://www.epa.gov/rcra

European Standards. (2013). *EN 15804+A1 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.*

IARC. (2001). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Man-made Vitreous Fibres. *81*.

ISO. (2006). *ISO 14044: Environmental management - Life cycle assessment - Requirements and guidelines.*

ISO. (2009). *ISO 14040: Environmental management - Life cycle assessment - principles and frameworks.*

ISO. (2011). *ISO 14025: Environmental labels and declarations - Type III environmental declarations - principles and procedures.*

ISO. (2017). *ISO 21930 Sustainability in building construction - Environmental declaration of building products.*

Marchant, G. E., Amen, M. A., Bullock, C. H., Carter, C. M., Johnson, K. A., Reynolds, J. W., . . . Crane, A. E. (2002). A Synthetic Vitreous Fiber (SVF) Occupational Exposure Database: Implementing the SVF Health and Safety

[1] This is a mechanical irritation and does not meet the U.S. OSHA HAZCOM definition of “Irritation” specified in Appendix A to 29 C.F.R. § 1910. 1200.

Partnership Program. *Applied Occupational and Environment Hygiene, 17*(4), 276-285.

Marchant, G., Bullock, C., Carter, C., Connelly, R., Crane, A., Fayerweather, W., . . . Reynolds, J. (2009). Applications and Findings of an Occupational Exposure Database for Synthetic Vitreous Fibers. *Journal of Occupational and Environmental Hygiene, 6*(3), 143-150.

thinkstep. (2018). GaBi LCA Database Documentation.

UL Environment. (2018). *PCR Guidance for Building-Related Products and Services - Part B: Building Envelope Thermal Insulation EPD Requirements.*

UL Environment. (2018). *Product Category Rules for Building-Related Products and Services - Part A: Life Cycle Assessment Calculation Rules and Report Requirements, v3.2.*

US DHHS. (2004). *Toxicological Profile for Synthetic Vitreous Fibers.*

8. Contact Information

8.1. Study Commissioner

NAIMA
NORTH AMERICAN INSULATION MANUFACTURERS ASSOCIATION

North American Manufacturers Insulation Association
11 Canal Center Plaza, Suite 103
Alexandria, VA 22314
(P) +1 703-684-0084
(F) +1 703-684-0427
www.naima.org

8.2. LCA Practitioner

thinkstep

thinkstep, Inc.
170 Milk St, 3rd floor
Boston, MA 02109
+1 (617) 247-4477
info@thinkstep.com
http://www.thinkstep.com