LIFE CYCLE ASSESSMENT (LCA)
OF KNAUF INSULATION AND MANSON INSULATION PRODUCTS

Public version

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Status Final

Client Knauf Insulation and Manson Insulation

Date July 2018

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1 INTRODUCTION

1.1 Opportunity

Knauf Insulation is striving to develop and bring to market products and solutions that will be vital in supporting the construction sector to deliver a low energy and sustainable built environment. To honor our commitment to sustainability, it is important that we conduct Life Cycle Assessments to evaluate the environmental impacts of our products in all stages of life, from raw materials to manufacturing and through to the end of life. The goal of conducting a Life Cycle Assessment is to explore the full range of environmental impacts our products have and to identify ways to improve processes and reduce impacts. This project is critical to Knauf Insulation's commitment to provide the market with the information it needs to be able to properly assess the environmental impact of our products/solutions.

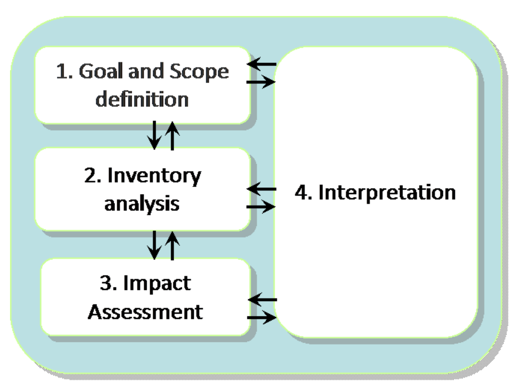
In order to understand the true impact of products throughout all life cycle stages, Knauf Insulation has chosen to conduct the Life Cycle Assessment using a cradle-to-grave approach. By factoring in all stages, we are more informed on how to reduce impacts on a broader scale.

Knauf Insulation is interested in having Life Cycle Assessment (LCA) data available for its most important products to be able to obtain a Sustainable Minds Transparency Report™, a Type III Environmental Declaration that can be used for communication with and amongst other companies, architects, and consumer communication, and that can also be utilized in whole building LCA tools in conjunction with the LCA background report and LCI.

Knauf Insulation commissioned Sustainable Minds to help develop LCAs for our most important insulation products. Knauf Insulation wants to learn from the results and is looking forward to having guidance for future product improvements that can be deduced from the results.

1.2 Life Cycle Assessment

This life cycle assessment (LCA) follows the UL Environment (ULE) PCR for Building Envelope Thermal Insulation v2.0, which was updated and republished under the Part A and Part B format to conform to EN 15804 and ISO 21930:2017 [1]. This report includes the following phases:



Source: ISO 14040

- Goal and Scope
- Inventory Analysis
- Impact Assessment
- Interpretation

An ISO 14040-44 third-party review and a third-party report verification for Transparency Reports are required in order to use

Transparency Reports as Type III Environmental Declarations. The third-party review and third-party Transparency Report verification will both be completed in this project.

1.3 Status

All information in this report reflects the best possible inventory by Knauf Insulation at the time it was collected, and best practices were conducted by Sustainable Minds and Knauf Insulation employees to transform this information into this LCA report. The data covers annual manufacturing data for 10/2015-09/2016 from three of Knauf Insulation's manufacturing locations: Shelbyville, IN; Lanett, AL; and Shasta Lake, CA. Where data was missing, assumptions were made from manufacturing data for the three facilities based upon expertise from Knauf Insulation employees.

This study includes primary data from the processes at the three manufacturing facilities, secondary data from vendors that have been contracted, and literature data to complete the inventory and fill gaps where necessary.

Knauf Insulation has chosen to have the LCA report undergo third-party review and the Transparency Reports undergo third-party verification. This review and verification will be performed by NSF to assess conformance to ISO 14040/14044 and the ULE PCRs.

1.4 Team

This report is based on the work of the following LCA project team members on behalf of Knauf Insulation:

- Scott Miller, Director Knauf Academy

Scott has been assisted by numerous Knauf Insulation employees during the data collection, reporting, and interpretation phases.

From Sustainable Minds:

- Kim Lewis, LCA Practitioner

1.5 Structure

This report follows the following structure:

- Chapter 2: Goal and scope
- Chapter 3: Inventory analysis
- Chapter 4: Impact assessment
- Chapter 5: Interpretation
- Chapter 6: Sources

This report includes LCA terminology. To assist the reader, special attention has been given to list definitions of important terms used at the end of this report.

2 GOAL AND SCOPE

This chapter explains the starting points for the LCA. The aim of the goal and scope is to define the products under study and the depth and width of the analysis.

2.1 Intended application and audience

This report intends to define the specific application of the LCA methodology to the life cycle of Knauf Insulation products. It is intended for both internal and external purposes. The intended audience includes the program operator (Sustainable Minds) and reviewers who will be assessing the LCA for conformance to the PCRs, as well as Knauf internal stakeholders involved in marketing and communications, operations, and design. Results presented in this document are not intended to support comparative assertions within this study. However, the results will be disclosed to the public in Sustainable Minds Transparency Reports (Type III Environmental Declarations per ISO 14025) which are focused on products that are available in the US market. These Transparency Reports will undergo critical review for conformance to the PCRs.

2.2 Insulation products

With more than 30 years of experience in the insulation industry, Knauf Insulation represents one of the fastest growing and most respected names in insulation worldwide. As a manufacturer of fiberglass insulation products, Knauf Insulation is interested in demonstrating its sustainability leadership and leveraging business value associated with transparent reporting of its products' cradle-to-grave environmental impacts. For more information on Knauf Insulation products, go to http://www.knaufinsulation.com/en.

In addition to the Knauf-branded products, Manson-branded products are also being evaluated in this study. Here is a list of the Knauf products with their Manson counterparts, which are exactly the same from cradle to grave as their Knauf counterparts except for branding (i.e. the way ink is printed on the packaging) [7]:

Knauf brand name	**Manson brand name**
Atmosphere™ Duct Wrap	ALLEY WRAP™ B
Atmosphere™ Duct Liner	AKOUSTI-LINER™
Black Acoustical Board	Akousti-Board Black™
Earthwool® Insulation Board	AK BOARD™
Wall and Ceiling Liner M	AKOUSTI-SHIELD™

The Manson product Manson Alley K Pipe Insulation is the same as Knauf Earthwool Pipe Insulation with a de minimis exception, and it was not part of this updated LCA due to the unavailability of a new PCR for mechanical products at the time of publication. The LCA for pipe insulation will be updated when a new mechanical insulation PCR is available. See "Knauf Insulation Products LCA Background Report, Knauf 2017" for the LCA results for pipe insulation.

The products studied in this report are listed in Table 2.2a with their facing options specified where applicable. Some products in this report have previously been studied as part of an LCA, also indicated in Table 2.2a. Manufacturing locations, declaration names with products represented and type of declaration, and other product information for each product are listed in Tables 2.2b, 2.2c, and 2.2d, respectively.

Different than the 2017 Knauf LCA study, some products which were previously combined into an average declaration have now been separated to conform to the new ULE Part A v3.1 section 2.5.2 rules regarding variation. Sets of results which are required by the PCR are now reported separately per product within their respective Transparency Reports.

- For EcoBatt® Insulation, faced products differed in at least one environmental impact indicator by more than 10%; therefore, they were not combined as an average.
- For Atmosphere™ Duct Wrap and ALLEY WRAP™ B, faced and unfaced product differed in at least one environmental impact indicator by more than 10%; therefore, they were not combined as an average.
- For Earthwool® Insulation Board and AK BOARD™, faced products differed in at least one environmental impact indicator by more than 10%; therefore, they were not combined as an average.

Black Acoustical Board and Acoustical Smooth Board differed less than 10% for all environmental impact indicators, and the weighted coefficient of variation across all products was less than 20% for any impact category; therefore, they remained combined as an average.

Table 2.2a Product names and facing options

Product name	Facing options	Previous LCA
EcoBatt® Insulation	Unfaced	Yes
	Kraft	Yes
	FSK	No
	Foil	No
Jet Stream® Ultra Blowing Wool Insulation	N/A	Yes
EcoFill™ Wx Blowing Wool Insulation	N/A	Yes
JetSpray™ Thermal Insulation	N/A	No
Atmosphere™ Duct Liner and AKOUSTI-LINER™	N/A	No
Wall and Ceiling Liner M and AKOUSTI-SHIELD™	N/A	No
Atmosphere™ Duct Wrap and ALLEY WRAP™ B	Unfaced	No
	FSK	No
KN Utility Insulation	N/A	No
Black Acoustical Board and Akousti-Board Black™	N/A	No
Acoustical Smooth Board	N/A	No
Earthwool® Insulation Board and AK BOARD™	Unfaced	No
	ASJ+	No
	FSK	No

Table 2.2b Manufacturing locations

Product name	Manufacturing location(s)
EcoBatt® Insulation	Shelbyville, IN and Shasta Lake, CA
Jet Stream® Ultra Blowing Wool Insulation	Shelbyville, IN and Shasta Lake, CA
EcoFill™ Wx Blowing Wool Insulation	Shelbyville, IN and Shasta Lake, CA
JetSpray™ Thermal Insulation	Shelbyville, IN and Shasta Lake, CA
Atmosphere™ Duct Liner and AKOUSTI-LINER™	Shelbyville, IN
Wall and Ceiling Liner M and AKOUSTI-SHIELD™	Shelbyville, IN
Atmosphere™ Duct Wrap and ALLEY WRAP™ B	Shelbyville, IN; Lanett, AL; Shasta Lake, CA
KN Utility Insulation	Shelbyville, IN; Lanett, AL; Shasta Lake, CA
Black Acoustical Board and Akousti-Board Black™	Shelbyville, IN
Acoustical Smooth Board	Shelbyville, IN
Earthwool® Insulation Board and AK BOARD™	Shelbyville, IN

Table 2.2c Declaration names with products represented and type of declaration

Transparency Report name	Product name(s)	Type of declaration
EcoBatt® Insulation	EcoBatt® Insulation unfaced EcoBatt® Insulation kraft-faced EcoBatt® Insulation foil-faced EcoBatt® Insulation FSK-faced	Four specific products as an average from several of the manufacturer's plants
Jet Stream® Ultra and EcoFill™ Wx Blowing Wool Insulation	Jet Stream® Ultra Blowing Wool Insulation EcoFill™ Wx Blowing Wool Insulation	A specific product as an average from several of the manufacturer's plants
JetSpray™ Thermal Insulation	JetSpray™ Thermal Insulation	A specific product as an average from several of the manufacturer's plants
Atmosphere™ Duct Liner & Wall and Ceiling Liner M	Atmosphere™ Duct Liner Wall and Ceiling Liner M	A specific product from a manufacturer's plant
AKOUSTI-LINER™ and AKOUSTI-SHIELD™	AKOUSTI-LINER™ AKOUSTI-SHIELD™	A specific product from a manufacturer's plant
Atmosphere™ Duct Wrap and KN Utility Insulation	Atmosphere™ Duct Wrap unfaced Atmosphere™ Duct Wrap FSK-faced KN Utility Insulation	Three specific products as an average from several of the manufacturer's plants
ALLEY WRAP™ B	ALLEY WRAP™ B unfaced ALLEY WRAP™ B FSK-faced	Two specific products as an average from several of the manufacturer's plants
Black Acoustical Board and Acoustical Smooth Board	Black Acoustical Board Acoustical Smooth Board	An average product from a manufacturer's plant
Akousti-Board Black™	Akousti-Board Black™	A specific product from a manufacturer's plant
Earthwool® Insulation Board	Earthwool® Insulation Board unfaced Earthwool® Insulation Board FSK-faced Earthwool® Insulation Board ASJ+-faced	Three specific products from a manufacturer's plant
AK BOARD™	AK BOARD™ unfaced AK BOARD™ FSK-faced AK BOARD™ ASJ+-faced	Three specific products from a manufacturer's plant

Table 2.2d Other product information

Transparency Report name	CSI MasterFormat® classification	Application	ASTM or ANSI product specification
EcoBatt® Insulation	07 21 00	Thermal and acoustical barriers for energy-efficient construction. They can be used in new and retrofit wood and metal frame applications in residential and commercial structures, as well as in manufactured housing. These applications include thermal and acoustical treatments to walls, ceilings and floors.	• ASTM C 665; Type 1, Class A (unfaced) • ASTM C 665; Type II, Class C (kraft faced) • ASTM C 665; Type III, Class A (FSK-25 foil faced) • ASTM C 665; Type III, Class B (foil faced)
Jet Stream® Ultra and EcoFill™ Wx Blowing Wool Insulation	07 21 26	At the installation site, loose fill is installed using a blowing wool machine and blown into open attics or closed cavities. It can be used to dense-pack sidewalls using the drill and fill technique common in retrofitting homes or in home weatherization activities.	• ASTM C764; Type I
JetSpray™ Thermal Insulation	07 21 29	Spray-on insulation system installed using a blowing wool machine and water pump, used to activate the powdered adhesive. It is sprayed onto exterior and interior cavity walls for thermal and acoustical performance.	• ASTM C1014
Atmosphere™ Duct Liner & Wall and Ceiling Liner M	07 21 00	Specifically designed for sheet metal ducts used in heating, ventilating, and air conditioning. It provides an optimum combination of efficient sound absorption, low thermal conductivity, and minimal airstream surface friction. Wall & Ceiling Liner is designed for use as an acoustical and visual barrier for walls and ceilings where a black surface is required. It is primarily used in theaters, sound studios, public concourses and other areas where acoustical treatment is needed.	• ASTM C1071; Type I • ASTM C 665
AKOUSTI-LINER™ and AKOUSTI-SHIELD™	07 21 00	Specifically designed for sheet metal ducts used in heating, ventilating, and air conditioning. It provides an optimum combination of efficient sound absorption, low thermal conductivity, and minimal airstream surface friction. Wall & Ceiling Liner is designed for use as an acoustical and visual barrier for walls and ceilings where a black surface is required. It is primarily used in theaters, sound studios, public concourses and other areas where acoustical treatment is needed.	• ASTM C1071; Type I • ASTM C 665
Atmosphere™ Duct Wrap and KN Utility Insulation	07 21 00	External insulation on commercial or residential heating or air conditioning ducts. It is suitable for the exterior of rectangular or round sheet metal ducts and spaces or surfaces where temperature and condensation must be controlled. KN Utility Insulation is used as thermal and/or acoustical insulation in the appliance, equipment, industrial, commercial, and marine markets. KN Insulation has been successfully used as a Red List free and formaldehyde-free core in double wall duct systems.	• ASTM C 1139 - unfaced; Type I, Type II; Grade 1 - 0.75 lb/ft3; Grade 2 - 1.0 lb/ft3; Grade 3 - 1.5 lb/ft3 (Duct Wrap) • ASTM C 553; Type I, II, III (Duct wrap) • ASTM C553: Type I, Type II (KN Utility Insulation)
ALLEY WRAP™ B	07 21 00	External insulation on commercial or residential heating or air conditioning ducts. It is suitable for the exterior of rectangular or round sheet metal ducts and spaces or surfaces where temperature and condensation must be controlled. KN Utility Insulation is used as thermal and/or acoustical insulation in the appliance, equipment, industrial, commercial, and marine markets. KN Insulation has been successfully used as a Red List free and formaldehyde-free core in double wall duct systems.	• ASTM C 1139 - unfaced; Type I, Type II; Grade 1 - 0.75 lb/ft3; Grade 2 - 1.0 lb/ft3; Grade 3 - 1.5 lb/ft3 • ASTM C 553; Type I, II, III
Black Acoustical Board and Acoustical Smooth Board	07 21 13	Designed for use as acoustical insulation and/or a visual barrier on walls and ceilings, where system design requires a rigid product and where additional strength and abuse resistance	• ASTM C612; Type IA and Type IB

		are required. The black surface provides a visual barrier with an aesthetic appearance, in both wall and ceiling applications. Acoustical Smooth Board is a versatile product fitting for a variety of acoustical applications such as office partitions, interior panels, and sound baffles.	
Akousti-Board Black™	07 21 13	Designed for use as acoustical insulation and/or a visual barrier on walls and ceilings, where system design requires a rigid product and where additional strength and abuse resistance are required. The black surface provides a visual barrier with an aesthetic appearance, in both wall and ceiling applications.	• ASTM C612; Type IA and Type IB
Earthwool® Insulation Board	07 21 13	Versatile product for thermal and acoustical applications such as: heating and air conditioning ducts, power and process equipment, boiler and stack installations, metal and masonry walls, wall and roof panel systems, curtain wall assemblies, and cavity walls.	• ASTM C612: Type IA (1.6, 2.25, 3.0, 4.25, 6.0 pcf), Type IB (3.0, 4.25, 6.0 pcf) • ASTM C795 • ASTM C1136: Type I, II, III, IV, VIII (ASJ+), Type II, IV (FSK)
AK BOARD™	07 21 13	Versatile product for thermal and acoustical applications such as: heating and air conditioning ducts, power and process equipment, boiler and stack installations, metal and masonry walls, wall and roof panel systems, curtain wall assemblies, and cavity walls.	• ASTM C612: Type IA (1.6, 2.25, 3.0, 4.25, 6.0 pcf), Type IB (3.0, 4.25, 6.0 pcf) • ASTM C795 • ASTM C1136: Type I, II, III, IV, VIII (ASJ+), Type II, IV (FSK)

2.3 Functional unit

The results of the LCA in this report are expressed in terms of a functional unit, as it covers the entire life cycle of the products. Per the PCR [1], the functional unit is:

> 1 m^2 of installed insulation material with a thickness that gives an average thermal resistance R_{SI} = 1 $m^2 \cdot K/W$ and with a building service life of 75 years (packaging included)

Building envelope thermal insulation is assumed to have a reference service life equal to that of the building, which in this case is 75 years [1]; however, the expected service life of fiber glass under ideal conditions is usually stated at 100 years or more [7]. Therefore, the insulation does not need to be replaced, and 1 m^2 of insulation plus facing and packaging is required to fulfill the functional unit. This reference service life applies for the reference in-use conditions only.

Reference flows express the mass of product required to fulfill the functional or declared unit and are calculated based on the nominal insulation density for the R-value closest to R_{SI} = 1 $m^2 \cdot K/W$, which varies for each product. Reference flows are listed in Table 2.2e.

Table 2.2e Reference flows

Product	Facing options	Fiberglass (kg)	Adhered facing (kg)	Packaging (kg)	Thickness (m)	Weighted average reference flow total (kg)
EcoBatt® Insulation	Unfaced	[redacted]	0	0.0047	0.0472	0.4441
	Kraft	[redacted]	0.094	0.0046		
	FSK	[redacted]	0.144	0.0046		
	Foil	[redacted]	0.128	0.0046		
Jet Stream® Ultra Blowing Wool Insulation	N/A	[redacted]	0	0.0055	0.0133	0.3855
EcoFill™ Wx Blowing Wool Insulation	N/A	[redacted]	0	0.0055	0.0133	
JetSpray™ Thermal Insulation	N/A	[redacted]	0	0.0055	0.0366	1.029
Atmosphere™ Duct Liner and AKOUSTI-LINER™	N/A	[redacted]	0	0.0503	0.0386	0.9772
Wall and Ceiling Liner M and AKOUSTI-SHIELD™	N/A	[redacted]	0	0.0503	0.0386	
Atmosphere™ Duct Wrap and ALLEY WRAP™ B	Unfaced	[redacted]	0	0.0774	0.0515	0.7443
	FSK	[redacted]	0.144	0.0774		
KN Utility Insulation	N/A	[redacted]	0	0.0774	0.0515	
Black Acoustical Board and Akousti-Board Black™	N/A	[redacted]	0	0.0744	0.320	3.212
Acoustical Smooth Board	N/A	[redacted]	0	0.0744	0.320	
Earthwool® Insulation Board and AK BOARD™	Unfaced	[redacted]	0	0.0744	0.320	3.271
	ASJ+	[redacted]	0.220	0.0744		
	FSK	[redacted]	0.144	0.0744		

2.4 System boundaries

This section describes the system boundaries for products which have not been previously modeled, as indicated in Table 2.2a. Descriptions of the system boundaries for the other products can be found in their respective LCA reports [2, 3, 4].

The system boundaries define which life cycle stages are included and which are excluded. 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 nor incorporated into this analysis.

This LCA's system boundaries include the following life cycle stages:

- Raw materials acquisition
- Manufacturing
- Transportation
- Installation and maintenance
- Disposal/reuse/recycling

These boundaries apply to the modeled products and can be referred to as "cradle-to-grave" which means that it includes all life cycle stages and modules as identified in the PCRs [1].

The system boundaries for Knauf insulation products are detailed below. Figure 2.4a represents the life cycle stages for the entire life cycle of these products. Table 2.4a lists specific inclusions and exclusions for the system boundaries.

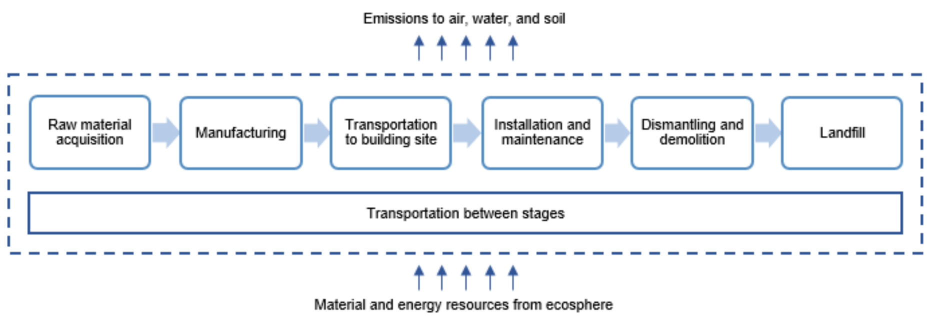


Figure 2.4a Applied system boundaries for the modeled insulation products

Table 2.4a System boundaries

Included	Excluded
• Raw material acquisition and processing • Processing of materials • Melting energy • Energy production • Transport of raw materials • Outbound transportation of products • Overhead energy (heating, lighting, forming, finishing, etc.) of manufacturing facilities • Packaging of final products • Installation and maintenance, including material loss, energy use, and auxiliary material requirements • End-of-life, including transportation	• Construction of major capital equipment • Maintenance and operation of support equipment • Human labor and employee transport • Manufacture and transport of packaging materials not associated with final product • Disposal of packaging materials not associated with final product • Building operational energy and water use

2.4.1. Raw materials acquisition and transportation (A1-A2)

The product stage includes, where relevant, the following processes:

- Extraction and processing of raw materials
- Average transport of raw materials from extraction/production to manufacturer
- Processing of recycled materials
- Transport of recycled/used materials to manufacturer

A description of the most important modeling parameters is included below.

2.4.2. Manufacturing (A3)

The manufacturing stage includes the following:
- Manufacturing of building envelope thermal insulation products
- Packaging
- Releases to environmental media (air, soil, ground and surface water)
- Manufacturing waste

2.4.3. Distribution (A4)

The transportation stage includes the following:
- Transportation of building envelope thermal insulation products from manufacturer to distributor/building site
- Transport of building envelope thermal insulation products from distributor to building site, if applicable

2.4.4. Installation (A5)

The installation stage includes the following:
- Installation on the building including any materials specifically required for installation
- Construction waste
- The reference service life of the building is defined as 75 years for building envelope thermal insulation, and the number of replacements of the insulation products will be declared accordingly. The number of replacements shall be calculated by dividing the reference service life of the building by the product service life as defined by the manufacturer's specifications.
- Releases to environmental media (air, soil, ground and surface water) of the product during installation and life of the product will be declared in accordance with current U.S. national standards and practice.
- Installation waste

2.4.5. Use (B1-B7)

The use stage includes:
- Product use
- Maintenance
- Repair
- Replacement
- Refurbishment
- Operational energy use
- Operational water use

2.4.6. Deconstruction (C1)

The deconstruction stage includes dismantling/demolition.

2.4.7. Transport (C2)

The transport stage includes transport from building site to final disposition.

2.4.8. Waste processing (C3)

The waste processing stage includes processing required before final disposition.

2.4.9. Disposal (C4)

The disposal stage includes final disposition (e.g. recycling/reuse/landfill/waste incineration/conversion to energy).

3 INVENTORY ANALYSIS

This chapter includes an overview of the obtained data and data quality that has been used in this study. For the complete life cycle inventory which catalogues the flows crossing the system boundary and provides the starting point for life cycle impact assessment, see the attached spreadsheets [5].

3.1 Data collection

Data used for this project represents a mix of primary data collected from Knauf on the production of the insulation products (gate-to-gate) and background data from the GaBi 2017 databases. Overall, the quality of the data used in this study is considered to be high and representative of the described systems. All appropriate means were employed to guarantee the data quality and representativeness as described below.

- **Gate-to-gate:** Data on processing materials and manufacturing the insulation products were collected in a consistent manner and level of detail to ensure high quality data. All submitted data were checked for quality multiple times on the plausibility of inputs and outputs. All questions regarding data were resolved with Knauf. Data were collected primarily at Knauf's Shelbyville, IN facility. Data for Atmosphere™ Duct Wrap (ALLEY WRAP™ B) and KN Utility Insulation were collected at all three facilities to ensure a more accurate representation of their production; for these products, the aggregated results represent a weighted average based on the total mass produced at each of the three facilities.

- **Background data:** All data from the GaBi 2017 database were created with consistent system boundaries and upstream data. Expert judgment and advice was used in selecting appropriate datasets to model the materials and energy for this study and has been noted in the preceding sections. Detailed database documentation for the GaBi datasets can be accessed at http://documentation.gabi-software.com/.

All primary data were provided by Knauf. Upon receipt, data were cross-checked for completeness and plausibility using mass balance, stoichiometry, and benchmarking. If gaps, outliers, or other inconsistencies occurred, Sustainable Minds engaged with Knauf to resolve any open issues.

3.2 Primary data

Loosefill fiberglass insulation is produced in several manufacturing steps that involve melting the glass materials and forming the fibers [3]. In the case of JetSpray, an adhesive is added during the fiber forming stage. The other insulation products represented in this study are produced in several manufacturing steps that involve melting the glass materials, forming the fibers, and shaping them into the final products; for these products, binder is added to hold the glass fibers together.

The finished products are then distributed to construction sites where they are installed, and the packaging is disposed (sent to landfill). Building envelope thermal insulation has a 75-year reference service life which is equal to that of the building. At end of life, the insulation is removed and disposed in a landfill. The flow charts in Figure 3.2a illustrate the life cycle of JetSpray and other fiberglass insulation products not previously modeled.

Data used in this analysis represent insulation production at Knauf. All available thicknesses and R-values are included for each product. Results were then scaled to reflect the functional unit.

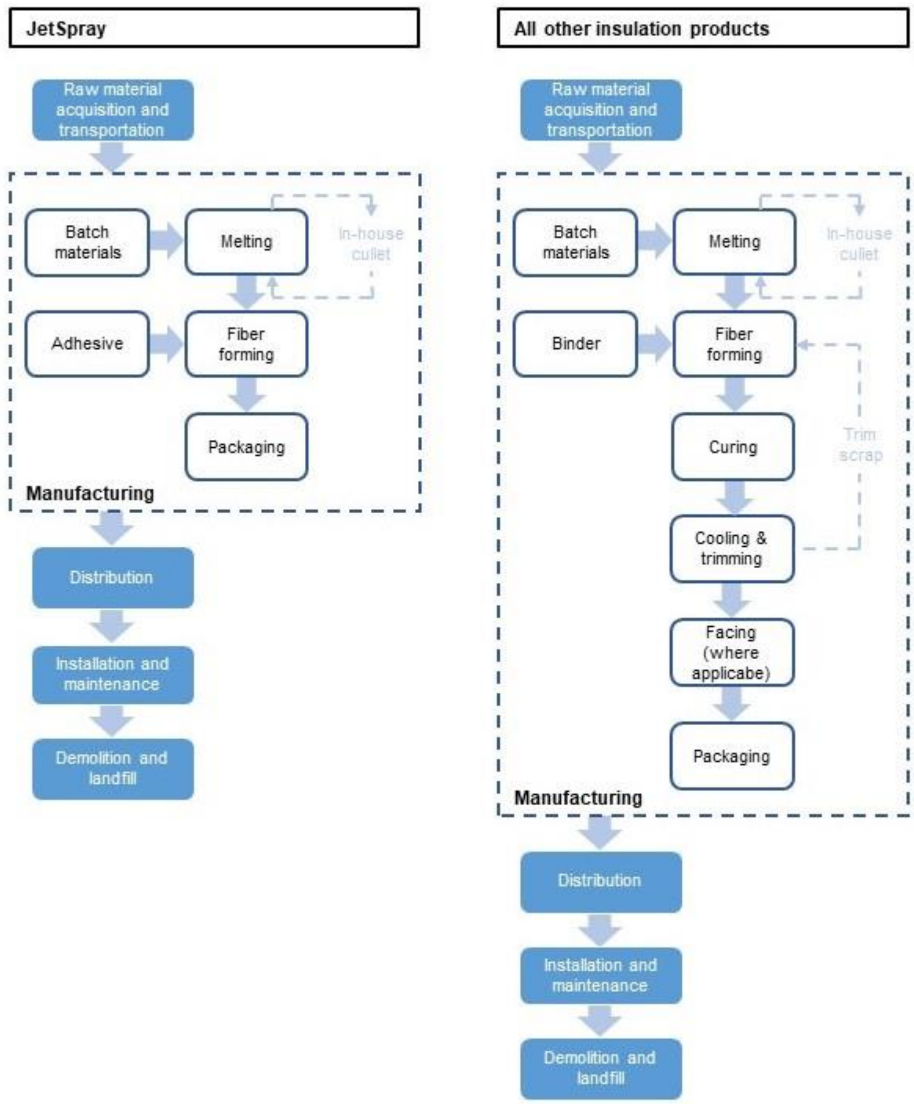


Figure 3.2a Life cycle flow chart of insulation products production

3.2.1. Raw Materials acquisition and transportation (A1-A2)

Raw materials acquisition and transportation represents the first stage of the insulation products life cycle. Sand, quicklime, soda, cullet, and other batch materials are transported to Knauf's facilities. Raw material inputs for products previously modeled can be found in their respective LCA reports [2, 3, 4]. Raw material inputs for the remaining products are listed in Tables 3.2a-o. As indicated in the tables, Knauf uses both in-house and post-consumer plate and bottle cullet in its batch. Internal cullet represents glass that is recycled internally, whereas Knauf obtains post-consumer cullet from external sources.

This cullet is assumed to arrive at Knauf burden-free aside from the transportation necessary to deliver it to Knauf's facilities. Like a number of fiberglass manufacturers, Knauf has been actively working to remove phenol formaldehyde from its binder and currently is using a new bio-based formulation.

The product does not contain substances that are identified as hazardous according to standards or regulations of the Resource Conservation and Recovery Act (RCRA), Subtitle C, nor does it (or its associated processes) release dangerous, regulated substances that affect health and environment, including indoor air emissions, gamma or ionizing radiation emissions, or chemicals released to the air or leached to water and soil [7].

It was assumed that foil and FSK facing is added with the same type and ratio of PVOH adhesive to batts and rolls as they are to duct wrap, as they are similar. The supplier and supplier location for those facing options were also assumed to be the same for duct wrap as for batts and rolls. All facing ingredients for the ASJ+, FSK, and foil facing were modeled. For JetSpray, the starch adhesive was modeled using dry starch as it was the only starch dataset available.

It should be noted that while packaging materials are listed as raw material inputs, their impacts lie within the manufacturing stage for this study. Since the functional unit includes packaging, it is simpler to compare the reference flow to the percentage of each input.

Raw materials are transported to Knauf's facilities via both rail and truck. Transport data were collected for each flow and are shown in Tables 3.2a-o for transportation to Shelbyville, IN unless otherwise noted.

Table 3.2a EcoBatt® FSK-faced raw material inputs

Flow	Mass percentage	Transportation mode	Distance (mi)
[redacted]	[redacted]	N/A	N/A
[redacted]	[redacted]	Truck and trailer	675
[redacted]	[redacted]	Truck and trailer	220

Table 3.2b EcoBatt® Foil-faced raw material inputs

Flow	Mass percentage	Transportation mode	Distance (mi)
[redacted]	[redacted]	N/A	N/A
[redacted]	[redacted]	Truck and trailer	675
[redacted]	[redacted]	Truck and trailer	220

Table 3.2c Average EcoBatt® Insulation raw material percentages [4, 6]

Flow	Mass percentage
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
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[redacted]	[redacted]
[redacted]	[redacted]

Numbers shown in **purple** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

Table 3.2d JetSpray™ Thermal Insulation raw material inputs

Flow	Mass percentage	Transportation mode	Distance (mi)
[redacted]	[redacted]	[3]	[3]
[redacted]	[redacted]		
[redacted]	[redacted]		
[redacted]	[redacted]		
[redacted]	[redacted]		
[redacted]	[redacted]		
[redacted]	[redacted]		
[redacted]	[redacted]		
[redacted]	[redacted]		
[redacted]	[redacted]		
[redacted]	[redacted]		
[redacted]	[redacted]	Truck and trailer	681

Table 3.2e Atmosphere™ Duct Liner and Wall and Ceiling Liner M (and AKOUSTI-LINER™ and AKOUSTI-SHIELD™) raw material inputs

Flow	Mass percentage	Transportation mode	Distance (mi)
[redacted]	[redacted]	Truck and trailer	176
[redacted]	[redacted]	Rail	1402
[redacted]	[redacted]	Truck and trailer	62
[redacted]	[redacted]	Truck and trailer	238
[redacted]	[redacted]	Truck and trailer	625
[redacted]	[redacted]	Rail	2076
[redacted]	[redacted]	Rail	273
[redacted]	[redacted]	Rail	214
[redacted]	[redacted]	Truck and trailer	578
[redacted]	[redacted]	N/A	N/A
[redacted]	[redacted]	Truck and trailer	224
[redacted]	[redacted]	Truck and trailer	639
[redacted]	[redacted]	Truck and trailer	329
[redacted]	[redacted]	Truck and trailer	497
[redacted]	[redacted]	Truck and trailer	786
[redacted]	[redacted]	Truck and trailer	314
[redacted]	[redacted]	Truck and trailer	423
[redacted]	[redacted]	Truck and trailer	423
[redacted]	[redacted]	Truck and trailer	423

Table 3.2f Atmosphere™ Duct Wrap unfaced (and ALLEY WRAP™ B unfaced) and KN Utility Insulation raw material inputs

Flow	Mass percentage, Shelbyville	Mass percentage, Lanett	Mass percentage, Shasta Lake	Transportation mode	Distance to Shelbyville (mi)	Distance to Lanett (mi)	Distance to Shasta Lake (mi)
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	177	64	237
[redacted]	[redacted]	[redacted]	[redacted]	Rail	1403	1785	574
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	76	150	216
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	238	150	675
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	825	N/A	N/A
[redacted]	[redacted]	[redacted]	[redacted]	Rail	2020	2127	533
[redacted]	[redacted]	[redacted]	[redacted]	Rail	149	84	2114
[redacted]	[redacted]	[redacted]	[redacted]	Rail	216	795	179
[redacted]	[redacted]	[redacted]	[redacted]	N/A	N/A	N/A	N/A
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	N/A	693	N/A
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	362	264	2066
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	142	707	207
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	73	90	167
[redacted]	[redacted]	[redacted]	[redacted]	Rail	334	788	2591
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	1044	625	414
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	566	77	585
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	1495	N/A	3717
[redacted]	[redacted]	[redacted]	[redacted]	Truck and trailer	566	391	585

Table 3.2g Atmosphere™ Duct Wrap FSK-faced (and ALLEY WRAP™ B FSK-faced) raw material inputs

Flow	Average mass percentage	Transportation mode	Distance to Shelbyville (mi)	Distance to Lanett (mi)	Distance to Shasta Lake (mi)
[redacted]	[redacted]	N/A	N/A	N/A	N/A
[redacted]	[redacted]	Truck and trailer	675	906	2824
[redacted]	[redacted]	Truck and trailer	220	114	213

Table 3.2h Average Atmosphere™ Duct Wrap and KN Utility Insulation raw material percentages

Flow	Mass percentage
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Numbers shown in **purple** have a variation of 10 to 20%

Numbers shown in **red** have a variation greater than 20%

Table 3.2i Average ALLEY WRAP™ B raw material percentages

Flow	Mass percentage
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Numbers shown in **purple** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

Table 3.2j Acoustical Smooth Board and unfaced Earthwool® Insulation Board raw material inputs

Flow	Mass percentage	Transportation mode	Distance (mi)
[redacted]	[redacted]	Truck and trailer	176
[redacted]	[redacted]	Rail	1402
[redacted]	[redacted]	Truck and trailer	62
[redacted]	[redacted]	Truck and trailer	238
[redacted]	[redacted]	Truck and trailer	625
[redacted]	[redacted]	Rail	2076
[redacted]	[redacted]	Rail	273
[redacted]	[redacted]	Rail	214
[redacted]	[redacted]	Truck and trailer	578
[redacted]	[redacted]	N/A	N/A
[redacted]	[redacted]	Truck and trailer	345
[redacted]	[redacted]	Truck and trailer	224
[redacted]	[redacted]	Truck and trailer	655
[redacted]	[redacted]	Truck and trailer	329
[redacted]	[redacted]	Truck and trailer	423
[redacted]	[redacted]	Truck and trailer	423

Table 3.2k Black acoustical board and Akousti-Board Black™ raw material inputs

Flow	Mass percentage	Transportation mode	Distance (mi)
[redacted]	[redacted]	N/A	N/A
[redacted]	[redacted]	Truck and trailer	786
[redacted]	[redacted]	Truck and trailer	314

Table 3.2l Average Black Acoustical Board and Acoustical Smooth Board raw material percentages

Flow	Mass percentage
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Numbers shown in **purple** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

Table 3.2m ASJ+-faced Earthwool® Insulation Board or AK BOARD™ raw material inputs

Flow	Mass percentage	Transportation mode	Distance (mi)
[redacted]	[redacted]	N/A	N/A
[redacted]	[redacted]	Truck and trailer	675
[redacted]	[redacted]	Truck and trailer	220

Table 3.2n FSK-faced Earthwool® Insulation Board or AK BOARD™ raw material inputs

Flow	Mass percentage	Transportation mode	Distance (mi)
[redacted]	[redacted]	N/A	N/A
[redacted]	[redacted]	Truck and trailer	675
[redacted]	[redacted]	Truck and trailer	220

Table 3.2o Average Earthwool® Insulation Board or AK BOARD™ raw material percentages

Flow	Mass percentage
[redacted]	[redacted]

Numbers shown in **purple** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

3.2.2. Manufacturing (A3)

After the batch materials are transported to Knauf's facilities, they are melted in a furnace. During this stage, fusion loss in glass occurs with approximately a 90% yield. The melted glass is then transferred to a fiberizer that transforms the melt into glass fibers. As they are formed, the fibers are sprayed with additives. For loosefill products, de-dusting and anti-static agents are added to reduce dust formed and clumping. For JetSpray, an adhesive is also added at this stage. Then these loosefill products are packaged and shipped to the construction site. For all other insulation products in this study, a binder is added that acts as an adhesive to hold the fibers together, and the products are compressed into continuous "rolls". These rolls are sent through a curing oven and subsequently cooled and trimmed to size. After curing, the exterior sanded down to ensure an even surface for the facing. Facing for faced products is applied before the insulation products are packaged and shipped to the construction site.

Manufacturing inputs and outputs for products previously modeled can be found in their respective LCA reports [2, 3, 4]. Annual manufacturing inputs and outputs for the remaining products are shown in Tables 3.2.2a-c. There are no additional manufacturing impacts associated with the addition of facing; therefore, results are presented independently of facing type. Water in the manufacturing stage is used to quench the fibers during fiberizing and to dilute the binder when spraying it onto the fibers. The majority of water consumed is evaporated in the curing oven for products which are cured. Emissions associated with the production of electricity and the combustion of natural gas are accounted for in the GaBi background processes. Stack emissions for carbon monoxide, NOx, and total particulate matter were provided based on Knauf's annual report to the Indiana Department of Environmental Management. Carbon dioxide emissions for the wrap products were allocated from federal reporting regulation Part 98. Carbon dioxide emissions for other products came from heating the batch (see the background data section of this report for more details).

Table 3.2.2a Atmosphere™ Duct Liner and Wall and Ceiling Liner M (and AKOUSTI-LINER™ and AKOUSTI-SHIELD™) annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity	[redacted]	MJ
	Natural gas	[redacted]	MJ
	Water	[redacted]	L
Outputs	Packaged product	[redacted]	kg
	Scrap	[redacted]	kg
	Total particulate	[redacted]	kg
	Carbon monoxide	[redacted]	kg

Table 3.2.2b Atmosphere™ Duct Wrap (and ALLEY WRAP™ B) and KN Utility Insulation annual manufacturing inputs and outputs

	Flow	Amount, Shelbyville	Amount, Lanett	Amount, Shasta Lake	Unit
Inputs	Electricity	[redacted]	[redacted]	[redacted]	MJ
	Natural gas	[redacted]	[redacted]	[redacted]	MJ
	Water	[redacted]	[redacted]	[redacted]	L
Outputs	Packaged product, including faced and unfaced	[redacted]	[redacted]	[redacted]	kg
	Scrap	[redacted]	[redacted]	[redacted]	kg
	Total particulate	[redacted]	[redacted]	[redacted]	kg
	NOx	[redacted]	[redacted]	[redacted]	kg
	Carbon monoxide	[redacted]	[redacted]	[redacted]	kg

Table 3.2.2c Board products annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity	[redacted]	MJ
	Natural gas	[redacted]	MJ
	Water	[redacted]	L
Outputs	Packaged product, including faced and unfaced	[redacted]	kg
	Scrap	[redacted]	kg
	Total particulate	[redacted]	kg
	Carbon monoxide	[redacted]	kg

3.2.3. Distribution (A4)

Products are packaged in the manufacturing plant and shipped directly to distributers, dealers, and showrooms for purchase by the end users in the US. Based on Knauf's records, liner, wrap, and board products are shipped by truck. Table 3.2.3 details insulation distribution assumptions [7]. Capacity utilization for liner, wrap, and board products are assumed to be 27%, the same as the capacity utilization for batts and rolls [4]. The insulation products arrive finished and require no further assembly

Table 3.2.3 Distribution assumptions for liner, wrap, and board products

Parameter	Value	Unit
Truck transport		
Average distance from Shelbyville to installation site	680	mi
Average distance from Lanett to installation site	580	mi
Average distance from Shasta Lake to installation site	884	mi
Capacity utilization by mass	27	%

3.2.4. Installation (A5)

At the installation site, insulation products are unpackaged and installed. Staples may be used to install batts, rolls, and board products, and tape may be used to install duct wrap and duct liner. For loosefill products, an insulation blower is typically used to install the product. The potential impact of the blower, staples, and tape is assumed to be negligible since their use is spread out over hundereds of bags of product; therefore, they were not included in the model.

No material is assumed to be lost or wasted. Scraps are typically used to fill corners or crevices. After installation, all packaging is assumed to be sent 100 miles to waste processing and disposed of according to the assumptions listed in the PCR:

Material type	Recycling rate	Landfill rate	Incineration rate
Plastics	15%	68%	17%
Pulp (cardboard, paper)	75%	20%	5%

The mass of packaging waste by type and the GWP based in the biogenic carbon content of the packaging (present in the disposal of paper or corrugated packaging) are shown in Tables 3.2.4a-g. Where only plastic packaging is used, the GWP based in the biogenic carbon content of the packaging is zero.

Table 3.2.4a Technical scenarios for packaging: EcoBatt® Insulation

Parameter	Value	Unit
Mass of plastic packaging waste	0.0046-0.0047	kg
GWP based in biogenic carbon content of plastic packaging	0	kg CO_2e

Table 3.2.4b Technical scenarios for packaging: Jet Stream® Ultra and EcoFill™ Wx Blowing Wool Insulation

Parameter	Value	Unit
Mass of plastic packaging waste	0.0055	kg
GWP based in biogenic carbon content of plastic packaging	0	kg CO_2e

Table 3.2.4c Technical scenarios for packaging: JetSpray™ Thermal Insulation

Parameter	Value	Unit
Mass of plastic packaging waste	0.0055	kg
GWP based in biogenic carbon content of plastic packaging	0	kg CO_2e

Table 3.2.4d Technical scenarios for packaging: Atmosphere™ Duct Liner & Wall and Ceiling Liner M and AKOUSTI-LINER™ and AKOUSTI-SHIELD™

Parameter	Value	Unit
Mass of paper packaging waste	0.0181	kg
Mass of plastic packaging waste	0.0322	kg
GWP based in biogenic carbon content of paper packaging	1.70E-02	kg CO_2e
GWP based in biogenic carbon content of plastic packaging	0	kg CO_2e

Table 3.2.4e Technical scenarios for packaging: Atmosphere™ Duct Wrap and KN Utility Insulation and ALLEY WRAP™ B

Parameter	Value	Unit
Mass of plastic packaging waste	0.0774	kg
GWP based in biogenic carbon content of plastic packaging	0	kg CO_2e

Table 3.2.4f Technical scenarios for packaging: Black Acoustical Board and Acoustical Smooth Board and Akousti-Board Black™

Parameter	Value	Unit
Mass of paper packaging waste	0.0225	kg
Mass of plastic packaging waste	0.0519	kg
GWP based in biogenic carbon content of paper packaging	2.72E-02	kg CO_2e
GWP based in biogenic carbon content of plastic packaging	0	kg CO_2e

Table 3.2.4g Technical scenarios for packaging: Earthwool® Insulation Board and AK BOARD™

Parameter	Value	Unit
Mass of paper packaging waste	0.0225	kg
Mass of plastic packaging waste	0.0519	kg
GWP based in biogenic carbon content of paper packaging	2.72E-02	kg CO_2e
GWP based in biogenic carbon content of plastic packaging	0	kg CO_2e

3.2.5. Use (B1-B7)

Insulation's reference service life is assumed to be equal to that of the building, which is 75 years for building envelope thermal insulation. No maintenance or replacement is required to achieve this product life span. Because the installed product is expected to remain undisturbed during the life of the building, there are assumed to be no impacts associated with the use stage.

3.2.6. Deconstruction (C1)

Removal at end of life requires human labor only and therefore does not contribute to the lifetime environmental impacts.

3.2.7. Transport (C2)

For results provided in the 2013 LCA reports, the C1-C4 stage was separated into individual modules by modeling the transportation to landfill and landfiling separately for each product, calculating the percentage of impacts for C2 and C4, and applying those percentages to the original results.

While fiberglass insulation can be recycled, doing so is not common practice in the industry. Therefore, after removal, the insulation is assumed to be transported 100 miles to the disposal site to be landfilled.

3.2.8. Waste processing (C3)

No waste processing is required before being landfilled.

3.2.9. Disposal (C4)

For results provided in the 2013 LCA reports, the C1-C4 stage was separated into individual modules by modeling the transportation to landfill and landfiling separately for each product, calculating the percentage of impacts for C2 and C4, and applying those percentages to the original results.

After removal, the insulation is assumed to be landfilled. Any biogenic carbon that is part of any binder is assumed to be sequestered in the landfill.

3.3 Data selection and quality

The data used to create the inventory model shall be as precise, complete, consistent, and representative as possible with regards to the goal and scope of the study under given time and budget constraints.

- Measured primary data is considered to be of the highest precision, followed by calculated and estimated data.
- Completeness is judged based on the completeness of the inputs and outputs per unit process and the completeness of the unit processes themselves. Wherever data were available on material and energy flows, these were included in the model.
- Consistency refers to modeling choices and data sources. The goal is to ensure that differences in results occur due to actual differences between product systems, and not due to inconsistencies in modeling choices, data sources, emission factors, or other.
- Representativeness expresses the degree to which the data matches the geographical, temporal, and technological requirements defined in the study's goal and scope.

An evaluation of the data quality with regard to these requirements is provided in the interpretation chapter of this report.

Time coverage. Primary data were collected on insulation production for October 2015 to September 2016. These dates were chosen in order to capture a representative picture of recycled content use at Knauf. Background data for upstream and downstream processes (i.e. raw materials, energy resources, transportation, and ancillary materials) were obtained from the GaBi databases.

Technology coverage. Data were collected for fiberglass insulation production at Knauf's facilities in the US.

Geographical coverage. Knauf's facilities are located in Shelbyville, IN; Lanett, AL; and Shasta Lake, CA. As such, the geographical coverage for this study is based on United States system boundaries for all processes and products. Whenever US background data were not readily available, European data or global data were used as proxies. Where multiple locations are used to produce the same product, results are presented as mass-weighted averages of production at each of the locations. Following production, insulation is shipped for use within the continental United States. Use and end-of-life impact were modeled using background data that represents average conditions for this region.

3.4 Background data

This section details background datasets used in modeling insulation product environmental performance. Each table lists dataset purpose, name, source, reference year, and location.

3.4.1. Fuels and energy

National and regional averages for fuel inputs and electricity grid mixes were obtained from the GaBi 2017 database. The grid mixes used for electricity are from the eGrid subregions (RFCW for Shelbyville, SRSO for Lanett, and CAMX for Shasta Lake) [8]. Table 3.4.1 shows the most relevant LCI datasets used in modeling the product systems.

Table 3.4.1 Key energy datasets used in inventory analysis

Energy	Dataset name	Primary source	Reference year	Geography
Electricity	Electricity grid mix – RFCW	ts	2012	US RFCW
Electricity	Electricity grid mix – SRSO	ts	2012	US SRSO
Electricity	Electricity grid mix – CAMX	ts	2012	US CAMX
Technical heat	Thermal energy from natural gas	ts	2012	US
Diesel	Diesel mix at refinery	ts	2013	US
Lubricants	Lubricants at refinery	ts	2013	US

3.4.2. Raw materials production

Data for up- and down-stream raw materials were obtained from the GaBi 2017 database. Table 3.4.2 shows the most relevant LCI datasets used in modeling the product systems. Documentation for the thinkstep datasets can be found at http://www.gabi-software.com/support/gabi/gabi-6-lci-documentation/. The only exceptions are the datasets for mineral oil, kraftliner, corrugated board, and LLDPE resin, which were obtained from USLCI and FEFCO databases within GaBi.

Table 3.4.2 Key material datasets used in inventory analysis

Raw material	Dataset name	Primary source	Reference year	Geography
Batch	Silica sand (Excavation and processing)	ts	2016	US
Batch	Soda (Na2CO3)	ts	2016	US
Batch	Limestone (CaCO3; washed)	ts	2016	US
Batch	Dolomite (ground)	ts	2016	US
Batch	Nepheline grinded	PE	2008	US
Batch	Borax (dehydrated)	ts	2016	US
Batch	Manganese oxide	PE	2008	AU
Batch	Silica sand (flour)	ts	2016	US
Binder	Glucose (via starch hydrolysis)	ts	2016	US
Binder	Hexamethylenediamine (HMDA; from adipic acid via adiponitrile)	ts	2016	US
Binder	Dimethyldichlorosilane by product chlorosilane	PE	2005	DE
Binder	Ammonium sulphate, by product acrylonitrile, hydrocyanic acid	ts	2016	US
Binder	Ammonia (NH3)	ts	2016	US
Binder	White mineral oil, at plan	USLCI/ts	2009	RNA
Binder	Lubricants at refinery	ts	2013	US
Binder	Diammonium phosphate (DAP, 18% N, 46% P2O5)	PE	2011	DE
Acrylic emulsion coating	Ethylene/methacrylic acid ionomer (EMAA)	ts	2016	US
JetSpray adhesive	Dried starch (corn wet mill) (economic allocation)	ts	2016	US
Facing	Polyvinyl alcohol (from vinyl acetate) (PVAL)	ts	2016	US
Facing	Aluminium foil	ts	2016	EU-28
Facing	Kraftliner (ThE sub.)	FEFCO	2006	US
Facing	Glass fibres	ts	2016	US
Facing	Rubber sealing compound (EN15804 A1-A3)	ts	2016	DE
Facing	Ethylene/methacrylic acid ionomer (EMAA)	ts	2016	US
Facing	Carbon black (furnace black; general purpose)	ts	2016	DE
Facing	Aluminium hydroxide from aluminium sulphate	ts	2016	DE
Facing	Polypropylene granulate (PP)	ts	2016	US
Facing	Tris(2-chloroisopropyl)phosphate (TCPP)	ts	2016	US
Facing	Aluminium hydroxide from aluminium sulphate	ts	2016	DE
Packaging	Polyethylene film (LDPE/PE-LD)	ts	2016	US
Packaging	Corrugated board (2015)	ts/FEFCO	2014	EU-27
Packaging	Polyethylene High Density Granulate (HDPE/PE-HD)	ts	2016	US
Packaging	Polyethylene High Density Granulate (HDPE/PE-HD)	ts	2016	US
Packaging	Kraft paper (EN15804 A1-A3)	ts	2016	EU-28
Packaging	Linear low density polyethylene resin, at plant	USLCI/ts	2009	RNA
Water	Process water	ts	2016	EU-28
Water	Water deionized (reverse-osmosis/electro-deionization)	ts	2016	US

3.4.3. Transportation

Average transportation distances and modes of transport are included for the transport of the raw materials to production facilities. Transport of the finished product to the construction site is also accounted for, along with the transportation of construction wastes and the deconstructed product at end of life to disposal facilities. Typical vehicles used include trailers and rail cars.

The GaBi datasets for transportation vehicles and fuels was used to model transportation. Truck transportation within the United States was modeled using the GaBi US truck transportation datasets. The vehicle types, fuel usage, and emissions for these transportation processes were developed based on the US Census Bureau Vehicle Inventory and Use Survey (2002) and US EPA emissions standards for heavy trucks. The 2002 VIUS survey is the last release in the VIUS study series on truck transportation fuel consumption and utilization ratios in the US, and the EPA emissions standards are the most appropriate data available for describing current US truck emissions.

3.4.4. Disposal

Disposal processes were obtained from the GaBi 2017 database. These processes were chosen to correspond to the material being disposed, specifically fiberglass and paper and plastic packaging. Since these materials do not decompose in a landfill, there are no energy recovery credits from landfill gas capture and combustion. The 'Glass/inert on landfill' data set was used for the fiberglass plus facing, as it was assumed to represent both faced and unfaced landfilled product. Table 3.4.4 reviews relevant disposal datasets used in the model.

Table 3.4.4 Key disposal datasets used in inventory analysis

Material disposed	Dataset name	Primary source	Year	Geography
Insulation	Glass/inert on landfill	ts	2016	US
Plastic	Plastic waste on landfill	ts	2016	EU-28
Paper	Paper waste on landfill	ts	2016	EU-28

3.4.5. Emissions to air, water, and soil

All gate-to-gate emissions reported by Knauf for the manufacturing stage are taken into account in the study. Emissions measured and reported by Knauf are detailed under primary data collection. Batch carbon dioxide emissions generated from certain materials (e.g., dolomite, limestone, soda ash, etc.) are not typically tracked or reported by glass mineral wool manufacturers. The batch composition dictates the quantity of carbon dioxide emitted at each facility due to decomposition and oxidation in the furnace. In this study, these emissions were calculated based on stoichiometry and are displayed in Table 3.4.5.

Table 3.4.5 Emission factors for batch materials

Batch material	Chemical formula	CO_2 emission factor*
Dolomite	$CaMg(CO_3)_2$	0.477 kg CO_2 / kg

Limestone	$CaCO_3$	0.440 kg CO_2 / kg
Soda ash	Na_2CO_3	0.415 kg CO_2 / kg

*Assumes all carbon contained in batch materials is converted to carbon dioxide

Data for all upstream materials, electricity, and energy carriers were obtained from the GaBi 2017 database. The emissions due to the use of electricity are accounted for within the database processes. Likewise, emissions from natural gas combustion are accounted for within the database process.

Emissions associated with transportation were determined by capturing the logistical operations. Energy use and the associated emissions were calculated using pre-configured transportation models from the GaBi 2017 database, adapted with transportation supplier data (specific fuel economy, specific emissions, etc.).

3.5 Limitations

Fiberglass insulation is assumed to have a reference service life equal to that of the building [7]. Thus, for example if the building has a 75-year service life, the insulation is likewise assumed to last 75 years with no maintenance. Although the building envelope thermal insulation PCR requires a functional unit of $R_{SI} = 1\ m^2{\cdot}K/W$ [1], it should be noted that a product with this R-value is not sold by Knauf. The declared product is delivered to the site of installation with the R-value chosen by the customer.

LCA results for Atmosphere™ Duct Wrap and KN Utility Insulation (and AKOUSTI-LINER™ and AKOUSTI-SHIELD™) represent a production volume weighted average of production at Knauf's three manufacturing facilities based on the total mass of these products produced. Data were collected from each of the three facilities. Differences in electric grid mix and in distribution distances between the three facilities are taken into account in this analysis. LCA results for all other products represent production volumes for the Shelbyville, IN facility.

Proxy data used in the LCA model were limited to background data for raw material production. US background data were used whenever possible, with European or global data substituted as proxies as necessary.

3.6 Criteria for the exclusion of inputs and outputs

Modeled inputs and outputs were re-examined according to new cut-off criteria provided in ISO 21930:2017. The only pieces of primary data which were not previously modeled have now been added: the facing ingredients for the ASJ+, FSK, and foil facing that fell below a previous 2% cut-off. The 2013 LCA reports were also re-examined according to the new cut-off criteria, and while packaging for inbound raw materials to Knauf was excluded, primary data for this was not provided, nor was it required under the scope of the PCR. Otherwise, all energy and material flow data available were included in the model and comply with the new cut-off criteria.

The cut-off criteria on a unit process level can be summarized as follows:

- All inputs and outputs to a (unit) process shall be included in the calculation of the pre-set parameters results, for which data are available. Data gaps shall be filled by conservative assumptions with average, generic or proxy data. Any assumptions for such choices shall be documented.

- Particular care should be taken to include material and energy flows that are known or suspected to release substances into the air, water or soil in quantities that contribute significantly to any of the pre-set indicators of this document. In cases of insufficient input data or data gaps for a unit process, the cut-off criteria shall be 1 % of renewable primary resource (energy), 1 % nonrenewable primary resource (energy) usage, 1 % of the total mass input of that unit process and 1 % of environmental impacts. The total of neglected input flows per module shall be a maximum of 5 % of energy usage, mass and environmental impacts. When assumptions are used in combination with plausibility considerations and expert judgement to demonstrate compliance with these criteria, the assumptions shall be conservative.
- All substances with hazardous and toxic properties that can be of concern for human health and/or the environment shall be identified and declared according to normative requirements in standards or regulation applicable in the market for which the EPD is valid, even though the given process unit is under the cut-off criterion of 1 % of the total mass.
-

In this report, no known flows are deliberately excluded; therefore, these criteria have been met. The completeness of the bill of materials defined in this report satisfies the above defined cut-off criteria.

Capital goods such as mixers, furnaces, fiberizers, curing ovens, and packaging lines are expected to last for the life of the plant, and the plant is expected to last about 30 years [7]. If 5,699,790 lb of board products are made in one year, then around 171 million lb of board products are made over the lifetime of the capital goods. Even if we ignore all other products being made, a functional unit reference flow of 7 lb means that only about 4.09E-06% of the capital goods and infrastructure are used per functional unit. Therefore, they are assumed not to significantly affect the conclusions of the LCA or additional environmental information.

3.7 Allocation

Whenever a system boundary is crossed, environmental inputs and outputs have to be assigned to the different products. Where multi-inputs or multi-outputs are considered, the same applies. The PCRs prescribe to report where and how allocation occurs in the modeling of the LCA. The allocation methods used were re-examined according to the updated allocation rules in ISO 21930:2017 and were determined to be in conformance; therefore, no updates to allocation methods were made. In this LCA, the following rules have been applied.

The model used in this report ensures that the sum of the allocated inputs and outputs of a unit process shall be equal to the inputs and outputs of the unit process before allocation. This means that no double counting or omissions of inputs or outputs through allocation is occurring.

The Knauf manufacturing facilities included in this report all produce multiple products. Since only facility level data were available, allocation among a facility's co-products was necessary to determine the input and output flows associated with each product. Allocation of materials and energy was done on a mass basis for all products except for the facing, which was allocated based on product area. Allocation of transportation was based on either weight or volume, depending on which was found to restrict the amount of cargo; the limiting factor was used in allocating transportation.

For recycled content and disposal at end of life, system boundaries were drawn consistent with the cut-off allocation approach. Cullet, which is used as part of Knauf's manufacturing process, is assumed to enter the system burden-free in that burden associated with the production of virgin glass is not allocated to the fiberglass life cycle. Likewise, the system boundary was drawn to include landfilling of fiberglass at end-of-life (following the polluter pays principle), but exclude any credits from material or energy recovery.

3.8 Software and database

The LCA model was created using the GaBi 7 Software system for life cycle engineering, developed by thinkstep. The GaBi 2017 LCI database provides the life cycle inventory data for several of the raw and process materials obtained from the background system [9].

3.9 Critical review

This is a supporting LCA report for fiberglass insulation Transparency Reports and will be evaluated for conformance to the PCRs according to ISO 14025 [10] and the ISO 14040/14044 standards [11].

4 IMPACT ASSESSMENT METHODS

4.1 Impact assessment

The environmental indicators as required by the PCRs are included as well as other indicators required to use the SM2013 Methodology [12] (see Table 4.1). The impact indicators are derived using the 100-year time horizon[1] factors, where relevant, as defined by TRACI 2.1 classification and characterization [13]. Long-term emissions (> 100 years) are not taken into consideration in the impact estimate. This follows the approach from the PCRs.

Table 4.1 Selected impact categories and units

Impact category	Unit
Acidification	kg SO_2 eq (sulphur dioxide)
Ecotoxicity	CTUe
Eutrophication	kg N eq (nitrogen)
Global warming	kg CO_2 eq (carbon dioxide)
Ozone depletion	kg CFC-11 eq
Carcinogenics	CTUh
Non-carcinogenics	CTUh
Respiratory effects	kg PM2.5 eq (fine particulates)
Smog	kg O_3 eq (ozone)
Fossil fuel depletion	MJ surplus

With respect to global warming potential, biogenic carbon is included in impact category calculations. Since Knauf's binder formulation includes bio-based materials, this leads to carbon sequestration in the landfill at end-of-life (assuming the binder itself does not degrade).

It shall be noted that the above impact categories represent impact potentials. They are approximations of environmental impacts that could occur if the emitted molecules would follow the underlying impact pathway and meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen functional unit (relative approach).

The results from the impact assessment indicate potential environmental effects and do not predict actual impacts on category endpoints, the exceedance of thresholds, or safety margins or risks.

4.2 Normalization and weighting

To arrive to a single score indicator, normalization [14] and weighting [15] conforming to the SM2013 Methodology were applied.

[1] The 100-year period relates to the period in which the environmental impacts are modeled. This is different from the time period of the functional unit. The two periods are related as follows: all environmental impacts that are created in the period of the functional unit are modeled through life cycle impact assessment using a 100-year time horizon to understand the impacts that take place.

Table 4.2 Normalization and Weighting factors

Impact category	Normalization	Weighting (%)
Acidification	90.9	3.6
Ecotoxicity	11000	8.4
Eutrophication	21.6	7.2
Global warming	24200	34.9
Ozone depletion	0.161	2.4
Carcinogenics	5.07E-05	9.6
Non carcinogenics	1.05E-03	6.0
Respiratory effects	24.3	10.8
Smog	1390	4.8
Fossil fuel depletion	17300	12.1

5 ASSESSMENT AND INTERPRETATION

This chapter includes the results from the LCA for the products studied. It details the results per product per functional unit, outlines the sensitivity analyses, and concludes with recommendations. Some products in this study reference and build onto products studied in other LCAs [2, 3, 4]. Updated LCI and LCIA data were provided by thinkstep for these products in order to obtain updated TRACI data [7]. These can be seen in the LCA results spreadsheets [5]. The results are presented per functional unit, sometimes for an average of similar products as outlined in Table 2.2c.

5.1 Resource use and waste flows

Resource use indicators, output flows and waste category indicators, and carbon emissions and removals are presented in this section. LCI flows were calculated with the help of the draft American Center for Life Cycle Assessment guide to the ISO 21930:2017 metrics [16].

Resource use indicators represent the amount of materials consumed to produce not only the insulation itself, but the raw materials, electricity, natural gas, etc. that go into the product's life cycle. Secondary materials used in the production of insulation include external recycled cullet.

Primary energy is an energy form found in nature that has not been subjected to any conversion or transformation process and is expressed in energy demand from renewable and non-renewable resources. Efficiencies in energy conversion are taken into account when calculating primary energy demand from process energy consumption. Water use represents total water used over the entire life cycle. No renewable energy was used in production, and no energy was recovered.

Non-hazardous waste is calculated based on the amount of waste generated during the manufacturing, installation, and disposal life cycle stages. There is no hazardous or radioactive waste associated with the life cycle. Additionally, all materials are assumed to be landfilled rather than incinerated or reused/recycled, so no materials are available for energy recovery or reuse/recycling. Waste occurs at product end-of-life when it is disposed to a landfill.

The biogenic carbon content of bio-based materials was reported per module. CO_2 from calcination and carbonation was assumed to be specific to cementitious products and therefore does not apply to this study. Carbon emissions from combustion were assumed to be zero because all waste is landfilled, not incinerated.

Tables 5.1a-o show resource use, output and waste flows, and carbon emissions and removals for all products per functional unit.

Table 5.1a Resource use, output and waste flows, and carbon emissions and removals for unfaced EcoBatt® Insulation per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	1.39E+00	8.01E-03	9.16E-05	0	0	0	0	0	0	0	0	1.10E-03	0	1.01E-02	**1.41E+00**
Renewable primary resources with energy content used as material	MJ, LHV	2.63E-03	0	3.19E-09	0	0	0	0	0	0	0	0	0	0	0	**2.63E-03**
Total use of renewable primary resources with energy content	MJ, LHV	1.39E+00	8.01E-03	9.16E-05	0	0	0	0	0	0	0	0	1.10E-03	0	1.01E-02	**1.41E+00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	8.69E+00	1.20E+00	2.75E-03	0	0	0	0	0	0	0	0	5.89E-02	0	1.96E-01	**1.01E+01**
Non-renewable primary resources with energy content used as material	MJ, LHV	1.02E-08	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.02E-08**
Total use of non-renewable primary resources with energy content	MJ, LHV	8.69E+00	1.20E+00	2.75E-03	0	0	0	0	0	0	0	0	5.89E-02	0	1.96E-01	**1.01E+01**
Secondary materials	kg	2.24E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**2.24E-01**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	4.91E+02	3.02E+00	7.00E-02	0	0	0	0	0	0	0	0	2.03E-01	0	7.35E+00	**5.02E+02**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	4.70E-03	0	0	0	0	0	0	0	0	0	0	3.48E-01	**3.53E-01**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	1.57E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.57E-03**
Biogenic Carbon Emission from Product	kg CO_2	4.33E-02	0	0	0	0	0	0	0	0	0	0	0	0	7.32E-04	**4.40E-02**
Biogenic Carbon Removal from Packaging	kg CO_2	1.27E-04	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.27E-04**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	1.13E-05	0	0	0	0	0	0	0	0	0	0	0	**1.13E-05**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1b Resource use, output and waste flows, and carbon emissions and removals for kraft-faced EcoBatt® Insulation per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	3.14E+00	1.02E-02	9.16E-05	0	0	0	0	0	0	0	0	1.39E-03	0	1.28E-02	**3.17E+00**
Renewable primary resources with energy content used as material	MJ, LHV	2.63E-03	0	3.19E-09	0	0	0	0	0	0	0	0	0	0	0	**2.63E-03**
Total use of renewable primary resources with energy content	MJ, LHV	3.15E+00	1.02E-02	9.16E-05	0	0	0	0	0	0	0	0	1.39E-03	0	1.28E-02	**3.17E+00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	1.15E+01	1.51E+00	2.75E-03	0	0	0	0	0	0	0	0	7.49E-02	0	2.49E-01	**1.33E+01**
Non-renewable primary resources with energy content used as material	MJ, LHV	1.02E-08	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.02E-08**
Total use of non-renewable primary resources with energy content	MJ, LHV	1.15E+01	1.51E+00	2.75E-03	0	0	0	0	0	0	0	0	7.49E-02	0	2.49E-01	**1.33E+01**
Secondary materials	kg	2.24E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**2.24E-01**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	6.13E+02	3.82E+00	7.00E-02	0	0	0	0	0	0	0	0	2.59E-01	0	9.35E+00	**6.26E+02**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	4.60E-03	0	0	0	0	0	0	0	0	0	0	4.42E-01	**4.47E-01**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	1.06E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.06E-01**
Biogenic Carbon Emission from Product	kg CO_2	4.33E-02	0	0	0	0	0	0	0	0	0	0	0	0	9.36E-02	**1.37E-01**
Biogenic Carbon Removal from Packaging	kg CO_2	1.27E-04	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.27E-04**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	1.13E-05	0	0	0	0	0	0	0	0	0	0	0	**1.13E-05**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1c Resource use, output and waste flows, and carbon emissions and removals for foil-faced EcoBatt® Insulation per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	3.22E+00	1.09E-02	9.16E-05	0	0	0	0	0	0	0	0	1.49E-03	0	1.37E-02	**3.24E+00**
Renewable primary resources with energy content used as material	MJ, LHV	2.65E-03	0	3.19E-09	0	0	0	0	0	0	0	0	0	0	0	**2.65E-03**
Total use of renewable primary resources with energy content	MJ, LHV	3.22E+00	1.09E-02	9.16E-05	0	0	0	0	0	0	0	0	1.49E-03	0	1.37E-02	**3.25E+00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	1.66E+01	1.63E+00	2.75E-03	0	0	0	0	0	0	0	0	8.03E-02	0	2.67E-01	**1.86E+01**
Non-renewable primary resources with energy content used as material	MJ, LHV	1.04E-08	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.04E-08**
Total use of non-renewable primary resources with energy content	MJ, LHV	1.66E+01	1.63E+00	2.75E-03	0	0	0	0	0	0	0	0	8.03E-02	0	2.67E-01	**1.86E+01**
Secondary materials	kg	2.24E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**2.24E-01**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	2.07E+03	4.11E+00	7.00E-02	0	0	0	0	0	0	0	0	2.77E-01	0	1.00E+01	**2.09E+03**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	4.60E-03	0	0	0	0	0	0	0	0	0	0	4.39E-01	**4.43E-01**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	1.06E-02	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.06E-02**
Biogenic Carbon Emission from Product	kg CO_2	4.33E-02	0	0	0	0	0	0	0	0	0	0	0	0	9.96E-04	**4.43E-02**
Biogenic Carbon Removal from Packaging	kg CO_2	1.27E-04	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.27E-04**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	1.13E-05	0	0	0	0	0	0	0	0	0	0	0	**1.13E-05**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1d Resource use, output and waste flows, and carbon emissions and removals for FSK-faced EcoBatt® Insulation per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	3.52E+00	1.13E-02	9.16E-05	0	0	0	0	0	0	0	0	1.55E-03	0	1.42E-02	**3.55E+00**
Renewable primary resources with energy content used as material	MJ, LHV	2.65E-03	0	3.19E-09	0	0	0	0	0	0	0	0	0	0	0	**2.65E-03**
Total use of renewable primary resources with energy content	MJ, LHV	3.52E+00	1.13E-02	9.16E-05	0	0	0	0	0	0	0	0	1.55E-03	0	1.42E-02	**3.55E+00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	1.73E+01	1.68E+00	2.75E-03	0	0	0	0	0	0	0	0	8.30E-02	0	2.76E-01	**1.93E+01**
Non-renewable primary resources with energy content used as material	MJ, LHV	1.05E-08	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.05E-08**
Total use of non-renewable primary resources with energy content	MJ, LHV	1.73E+01	1.68E+00	2.75E-03	0	0	0	0	0	0	0	0	8.30E-02	0	2.76E-01	**1.93E+01**
Secondary materials	kg	2.24E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**2.24E-01**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	2.33E+03	4.25E+00	7.00E-02	0	0	0	0	0	0	0	0	2.86E-01	0	1.04E+01	**2.35E+03**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	4.60E-03	0	0	0	0	0	0	0	0	0	0	4.50E-01	**4.55E-01**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	1.20E-02	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.20E-02**
Biogenic Carbon Emission from Product	kg CO_2	4.33E-02	0	0	0	0	0	0	0	0	0	0	0	0	1.03E-03	**4.43E-02**
Biogenic Carbon Removal from Packaging	kg CO_2	1.27E-04	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.27E-04**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	1.13E-05	0	0	0	0	0	0	0	0	0	0	0	**1.13E-05**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1e Resource use, output and waste flows, and carbon emissions and removals for Jet Stream® Ultra and EcoFill™ Wx Blowing Wool Insulation per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	Total
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	9.15E-01	2.83E-03	9.76E-04	0	0	0	0	0	0	0	0	1.15E-03	0	9.25E-03	**9.29E-01**
Renewable primary resources with energy content used as material	MJ, LHV	4.82E-13	0	3.02E-08	0	0	0	0	0	0	0	0	0	0	0	**3.02E-08**
Total use of renewable primary resources with energy content	MJ, LHV	9.15E-01	2.83E-03	9.76E-04	0	0	0	0	0	0	0	0	1.15E-03	0	9.25E-03	**9.29E-01**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	1.07E+01	5.16E-01	7.43E-02	0	0	0	0	0	0	0	0	6.44E-02	0	2.14E-01	**1.16E+01**
Non-renewable primary resources with energy content used as material	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Total use of non-renewable primary resources with energy content	MJ, LHV	1.07E+01	5.16E-01	7.43E-02	0	0	0	0	0	0	0	0	6.44E-02	0	2.14E-01	**1.16E+01**
Secondary materials	kg	2.29E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**2.29E-01**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	4.40E+02	1.04E+00	2.74E+00	0	0	0	0	0	0	0	0	2.22E-01	0	8.03E+00	**4.52E+02**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	5.50E-03	0	0	0	0	0	0	0	0	0	0	3.80E-01	**3.86E-01**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	1.78E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.78E-03**
Biogenic Carbon Emission from Product	kg CO_2	5.42E-02	0	0	0	0	0	0	0	0	0	0	0	0	8.00E-04	**5.50E-02**
Biogenic Carbon Removal from Packaging	kg CO_2	2.07E-04	0	0	0	0	0	0	0	0	0	0	0	0	0	**2.07E-04**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	2.12E-04	0	0	0	0	0	0	0	0	0	0	0	**2.12E-04**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1f Resource use, output and waste flows, and carbon emissions and removals for JetSpray™ Thermal Insulation per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	2.91E+00	7.54E-03	2.61E-03	0	0	0	0	0	0	0	0	3.07E-03	0	2.47E-02	**2.94E+00**
Renewable primary resources with energy content used as material	MJ, LHV	1.39E-12	0	8.06E-08	0	0	0	0	0	0	0	0	0	0	0	**8.06E-08**
Total use of renewable primary resources with energy content	MJ, LHV	2.91E+00	7.54E-03	2.61E-03	0	0	0	0	0	0	0	0	3.07E-03	0	2.47E-02	**2.94E+00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	2.84E+01	1.38E+00	1.98E-01	0	0	0	0	0	0	0	0	1.72E-01	0	5.71E-01	**3.07E+01**
Non-renewable primary resources with energy content used as material	MJ, LHV	1.539E-08	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.54E-08**
Total use of non-renewable primary resources with energy content	MJ, LHV	2.84E+01	1.38E+00	1.98E-01	0	0	0	0	0	0	0	0	1.72E-01	0	5.71E-01	**3.07E+01**
Secondary materials	kg	5.97E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**5.97E-01**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	1.16E+03	2.78E+00	7.33E+00	0	0	0	0	0	0	0	0	5.93E-01	0	2.15E+01	**1.20E+03**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	5.50E-03	0	0	0	0	0	0	0	0	0	0	1.02E+00	**1.03E+00**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	5.43E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	**5.43E-03**
Biogenic Carbon Emission from Product	kg CO_2	1.42E-01	0	0	0	0	0	0	0	0	0	0	0	0	2.14E-03	**1.44E-01**
Biogenic Carbon Removal from Packaging	kg CO_2	5.41E-04	0	0	0	0	0	0	0	0	0	0	0	0	0	**5.41E-04**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	5.67E-04	0	0	0	0	0	0	0	0	0	0	0	**5.67E-04**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1g Resource use, output and waste flows, and carbon emissions and removals for Atmosphere™ Duct Liner & Wall and Ceiling Liner M (and AKOUSTI-LINER™ and AKOUSTI-SHIELD™) per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	Total
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	2.46E+00	6.70E-02	2.62E-03	0	0	0	0	0	0	0	0	5.11E-03	0	4.46E-02	**2.58E+00**
Renewable primary resources with energy content used as material	MJ, LHV	3.38E-04	0	3.10E-07	0	0	0	0	0	0	0	0	0	0	0	**3.39E-04**
Total use of renewable primary resources with energy content	MJ, LHV	2.46E+00	6.70E-02	2.62E-03	0	0	0	0	0	0	0	0	5.11E-03	0	4.46E-02	**2.58E+00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	3.80E+01	2.75E+00	5.20E-02	0	0	0	0	0	0	0	0	2.10E-01	0	6.51E-01	**4.17E+01**
Non-renewable primary resources with energy content used as material	MJ, LHV	3.99E-08	0	3.18E-11	0	0	0	0	0	0	0	0	0	0	0	**3.99E-08**
Total use of non-renewable primary resources with energy content	MJ, LHV	3.80E+01	2.75E+00	5.20E-02	0	0	0	0	0	0	0	0	2.10E-01	0	6.51E-01	**4.17E+01**
Secondary materials	kg	5.29E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**5.29E-01**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	3.21E+02	7.52E+00	1.49E+00	0	0	0	0	0	0	0	0	5.74E-01	0	2.09E+01	**3.52E+02**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	5.03E-02	0	0	0	0	0	0	0	0	0	0	9.27E-01	**9.77E-01**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	2.67E-02	0	0	0	0	0	0	0	0	0	0	0	0	0	**2.67E-02**
Biogenic Carbon Emission from Product	kg CO_2	2.82E-02	0	0	0	0	0	0	0	0	0	0	0	0	1.91E-03	**3.01E-02**
Biogenic Carbon Removal from Packaging	kg CO_2	2.55E-02	0	0	0	0	0	0	0	0	0	0	0	0	0	**2.55E-02**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	6.15E-03	0	0	0	0	0	0	0	0	0	0	0	**6.15E-03**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1h Resource use, output and waste flows, and carbon emissions and removals for unfaced Atmosphere™ Duct Wrap (and ALLEY WRAP™ B) and KN Utility Insulation per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	Total
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	2.25E+00	7.94E-02	6.07E-03	0	0	0	0	0	0	0	0	5.78E-03	0	5.05E-02	**2.40E+00**
Renewable primary resources with energy content used as material	MJ, LHV	5.26E-04	0	9.17E-07	0	0	0	0	0	0	0	0	0	0	0	**5.27E-04**
Total use of renewable primary resources with energy content	MJ, LHV	2.25E+00	7.94E-02	6.08E-03	0	0	0	0	0	0	0	0	5.78E-03	0	5.05E-02	**2.40E+00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	4.51E+01	3.26E+00	1.17E-01	0	0	0	0	0	0	0	0	2.38E-01	0	7.36E-01	**4.95E+01**
Non-renewable primary resources with energy content used as material	MJ, LHV	3.115E-08	0	8.03E-11	0	0	0	0	0	0	0	0	0	0	0	**3.12E-08**
Total use of non-renewable primary resources with energy content	MJ, LHV	4.51E+01	3.26E+00	1.17E-01	0	0	0	0	0	0	0	0	2.38E-01	0	7.36E-01	**4.95E+01**
Secondary materials	kg	3.33E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**3.33E-01**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	4.76E+02	8.91E+00	3.30E+00	0	0	0	0	0	0	0	0	6.49E-01	0	2.36E+01	**5.13E+02**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	7.74E-02	0	0	0	0	0	0	0	0	0	0	6.19E-01	**6.96E-01**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	2.79E-02	0	0	0	0	0	0	0	0	0	0	0	0	0	**2.79E-02**
Biogenic Carbon Emission from Product	kg CO_2	4.18E-02	0	0	0	0	0	0	0	0	0	0	0	0	2.16E-03	**4.39E-02**
Biogenic Carbon Removal from Packaging	kg CO_2	6.20E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	**6.20E-03**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	3.29E-04	0	0	0	0	0	0	0	0	0	0	0	**3.29E-04**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1i Resource use, output and waste flows, and carbon emissions and removals for FSK-faced Atmosphere™ Duct Wrap (and ALLEY WRAP™ B) per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	Total
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	4.38E+00	9.58E-02	6.07E-03	0	0	0	0	0	0	0	0	6.98E-03	0	6.09E-02	**4.55E+00**
Renewable primary resources with energy content used as material	MJ, LHV	5.49E-04	0	9.17E-07	0	0	0	0	0	0	0	0	0	0	0	**5.50E-04**
Total use of renewable primary resources with energy content	MJ, LHV	4.38E+00	9.58E-02	6.08E-03	0	0	0	0	0	0	0	0	6.98E-03	0	6.09E-02	**4.55E+00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	5.37E+01	3.94E+00	1.17E-01	0	0	0	0	0	0	0	0	2.87E-01	0	8.89E-01	**5.89E+01**
Non-renewable primary resources with energy content used as material	MJ, LHV	3.15E-08	0	8.03E-11	0	0	0	0	0	0	0	0	0	0	0	**3.16E-08**
Total use of non-renewable primary resources with energy content	MJ, LHV	5.37E+01	3.94E+00	1.17E-01	0	0	0	0	0	0	0	0	2.87E-01	0	8.89E-01	**5. 89E+01**
Secondary materials	kg	3.33E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**3.33E-01**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	2.32E+03	1.08E+01	3.30E+00	0	0	0	0	0	0	0	0	7.84E-01	0	2.85E+01	**2.36E+03**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	7.74E-02	0	0	0	0	0	0	0	0	0	0	6.83E-01	**7.60E-01**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	3.84E-02	0	0	0	0	0	0	0	0	0	0	0	0	0	**3.84E-02**
Biogenic Carbon Emission from Product	kg CO_2	4.18E-02	0	0	0	0	0	0	0	0	0	0	0	0	2.61E-03	**4.44E-02**
Biogenic Carbon Removal from Packaging	kg CO_2	6.20E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	**6.20E-03**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	3.29E-04	0	0	0	0	0	0	0	0	0	0	0	**3.29E-04**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1k Resource use, output and waste flows, and carbon emissions and removals for Black Acoustical Board (and Akousti-Board Black™) per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	7.61E+00	3.09E-01	5.01E-03	0	0	0	0	0	0	0	0	2.43E-02	0	2.12E-01	**8.16E+00**
Renewable primary resources with energy content used as material	MJ, LHV	2.19E-03	0	6.21E-07	0	0	0	0	0	0	0	0	0	0	0	**2.19E-03**
Total use of renewable primary resources with energy content	MJ, LHV	7.61E+00	3.09E-01	5.01E-03	0	0	0	0	0	0	0	0	2.43E-02	0	2.12E-01	**8.16E+00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	1.48E+02	1.27E+01	9.90E-02	0	0	0	0	0	0	0	0	9.96E-01	0	3.09E+00	**1.65E+02**
Non-renewable primary resources with energy content used as material	MJ, LHV	1.16E-07	0	6.17E-11	0	0	0	0	0	0	0	0	0	0	0	**1.16E-07**
Total use of non-renewable primary resources with energy content	MJ, LHV	1.48E+02	1.27E+01	9.90E-02	0	0	0	0	0	0	0	0	9.96E-01	0	3.09E+00	**1.65E+02**
Secondary materials	kg	1.87E+00	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.87E+00**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	1.25E+03	3.46E+01	2.83E+00	0	0	0	0	0	0	0	0	2.72E+00	0	9.91E+01	**1.38E+03**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	7.44E-02	0	0	0	0	0	0	0	0	0	0	3.20E+00	**3.27E+00**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	1.12E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.12E-01**
Biogenic Carbon Emission from Product	kg CO_2	1.26E-01	0	0	0	0	0	0	0	0	0	0	0	0	9.06E-03	**1.35E-01**
Biogenic Carbon Removal from Packaging	kg CO_2	5.89E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	**5.89E-03**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	9.88E-03	0	0	0	0	0	0	0	0	0	0	0	**9.88E-03**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1l Resource use, output and waste flows, and carbon emissions and removals for average Black Acoustical Board and Acoustical Smooth Board per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	7.59E+00	3.03E-01	5.01E-03	0	0	0	0	0	0	0	0	2.38E-02	0	2.08E-01	**8.13E+00**
Renewable primary resources with energy content used as material	MJ, LHV	2.19E-03	0	6.21E-07	0	0	0	0	0	0	0	0	0	0	0	**2.19E-03**
Total use of renewable primary resources with energy content	MJ, LHV	7.59E+00	3.03E-01	5.01E-03	0	0	0	0	0	0	0	0	2.38E-02	0	2.08E-01	**8.13E+00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	1.47E+02	1.24E+01	9.90E-02	0	0	0	0	0	0	0	0	9.78E-01	0	3.03E+00	**1.63E+02**
Non-renewable primary resources with energy content used as material	MJ, LHV	1.16E-07	0	6.17E-11	0	0	0	0	0	0	0	0	0	0	0	**1.16E-07**
Total use of non-renewable primary resources with energy content	MJ, LHV	1.47E+02	1.24E+01	9.90E-02	0	0	0	0	0	0	0	0	9.78E-01	0	3.03E+00	**1.63E+02**
Secondary materials	kg	1.87E+00	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.87E+00**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	1.23E+03	3.40E+01	2.83E+00	0	0	0	0	0	0	0	0	2.67E+00	0	9.72E+01	**1.37E+03**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	7.44E-02	0	0	0	0	0	0	0	0	0	0	3.14E+00	**3.21E+00**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	1.11E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.11E-01**
Biogenic Carbon Emission from Product	kg CO_2	1.26E-01	0	0	0	0	0	0	0	0	0	0	0	0	8.89E-03	**1.34E-01**
Biogenic Carbon Removal from Packaging	kg CO_2	5.89E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	**5.89E-03**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	9.88E-03	0	0	0	0	0	0	0	0	0	0	0	**9.88E-03**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Numbers shown in **purple** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

Table 5.1m Resource use, output and waste flows, and carbon emissions and removals for unfaced Earthwool® Insulation Board (and AK BOARD™) per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	7.57E+00	2.97E-01	5.01E-03	0	0	0	0	0	0	0	0	2.33E-02	0	2.04E-01	**8.10E+00**
Renewable primary resources with energy content used as material	MJ, LHV	2.19E-03	0	6.21E-07	0	0	0	0	0	0	0	0	0	0	0	**2.19E-03**
Total use of renewable primary resources with energy content	MJ, LHV	7.57E+00	2.97E-01	5.01E-03	0	0	0	0	0	0	0	0	2.33E-02	0	2.04E-01	**8.10E+00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	1.46E+02	1.22E+01	9.90E-02	0	0	0	0	0	0	0	0	9.59E-01	0	2.97E+00	**1.62E+02**
Non-renewable primary resources with energy content used as material	MJ, LHV	1.16E-07	0	6.17E-11	0	0	0	0	0	0	0	0	0	0	0	**1.16E-07**
Total use of non-renewable primary resources with energy content	MJ, LHV	1.46E+02	1.22E+01	9.90E-02	0	0	0	0	0	0	0	0	9.59E-01	0	2.97E+00	**1.62E+02**
Secondary materials	kg	1.87E+00	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.87E+00**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	1.22E+03	3.33E+01	2.83E+00	0	0	0	0	0	0	0	0	2.62E+00	0	9.53E+01	**1.36E+03**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	7.44E-02	0	0	0	0	0	0	0	0	0	0	3.08E+00	**3.15E+00**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	1.10E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.10E-01**
Biogenic Carbon Emission from Product	kg CO_2	1.26E-01	0	0	0	0	0	0	0	0	0	0	0	0	8.72E-03	**1.34E-01**
Biogenic Carbon Removal from Packaging	kg CO_2	5.89E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	**5.89E-03**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	9.88E-03	0	0	0	0	0	0	0	0	0	0	0	**9.88E-03**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1n Resource use, output and waste flows, and carbon emissions and removals for FSK-faced Earthwool® Insulation Board (and AK BOARD™) per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	Total
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	9.70E+00	3.10E-01	5.01E-03	0	0	0	0	0	0	0	0	2.44E-02	0	2.13E-01	**1.02E+01**
Renewable primary resources with energy content used as material	MJ, LHV	2.22E-03	0	6.21E-07	0	0	0	0	0	0	0	0	0	0	0	**2.22E-03**
Total use of renewable primary resources with energy content	MJ, LHV	9.70E+00	3.10E-01	5.01E-03	0	0	0	0	0	0	0	0	2.44E-02	0	2.13E-01	**1.03E+01**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	1.54E+02	1.28E+01	9.90E-02	0	0	0	0	0	0	0	0	1.00E+00	0	3.11E+00	**1.71E+02**
Non-renewable primary resources with energy content used as material	MJ, LHV	1.16E-07	0	6.17E-11	0	0	0	0	0	0	0	0	0	0	0	**1.16E-07**
Total use of non-renewable primary resources with energy content	MJ, LHV	1.54E+02	1.28E+01	9.90E-02	0	0	0	0	0	0	0	0	1.00E+00	0	3.11E+00	**1.71E+02**
Secondary materials	kg	1.87E+00	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.87E+00**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	3.06E+03	3.49E+01	2.83E+00	0	0	0	0	0	0	0	0	2.74E+00	0	9.97E+01	**3.20E+03**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	7.44E-02	0	0	0	0	0	0	0	0	0	0	3.22E+00	**3.29E+00**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	1.21E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.21E-01**
Biogenic Carbon Emission from Product	kg CO_2	1.26E-01	0	0	0	0	0	0	0	0	0	0	0	0	9.12E-03	**1.35E-01**
Biogenic Carbon Removal from Packaging	kg CO_2	5.89E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	**5.89E-03**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	9.88E-03	0	0	0	0	0	0	0	0	0	0	0	**9.88E-03**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Table 5.1o Resource use, output and waste flows, and carbon emissions and removals for ASJ+-faced Earthwool® Insulation Board (and AK BOARD™) per functional unit [5]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	9.95E+00	3.18E-01	5.01E-03	0	0	0	0	0	0	0	0	2.50E-02	0	2.18E-01	**1.05E+01**
Renewable primary resources with energy content used as material	MJ, LHV	2.22E-03	0	6.21E-07	0	0	0	0	0	0	0	0	0	0	0	**2.22E-03**
Total use of renewable primary resources with energy content	MJ, LHV	9.95E+00	3.18E-01	5.01E-03	0	0	0	0	0	0	0	0	2.50E-02	0	2.18E-01	**1.05E+01**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	1.60E+02	1.30E+01	9.90E-02	0	0	0	0	0	0	0	0	1.03E+00	0	3.18E+00	**1.77E+02**
Non-renewable primary resources with energy content used as material	MJ, LHV	1.16E-07	0	6.17E-11	0	0	0	0	0	0	0	0	0	0	0	**1.16E-07**
Total use of non-renewable primary resources with energy content	MJ, LHV	1.60E+02	1.30E+01	9.90E-02	0	0	0	0	0	0	0	0	1.03E+00	0	3.18E+00	**1.77E+02**
Secondary materials	kg	1.87E+00	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.87E+00**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m3	3.03E+03	3.57E+01	2.83E+00	0	0	0	0	0	0	0	0	2.80E+00	0	1.02E+02	**3.17E+03**
Output flows and waste category indicators																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-hazardous waste disposed	kg	0	0	7.44E-02	0	0	0	0	0	0	0	0	0	0	3.29E+00	**3.37E+00**
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
Biogenic Carbon Removal from Product	kg CO_2	1.26E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.26E-01**
Biogenic Carbon Emission from Product	kg CO_2	1.26E-01	0	0	0	0	0	0	0	0	0	0	0	0	9.33E-03	**1.35E-01**
Biogenic Carbon Removal from Packaging	kg CO_2	5.89E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	**5.89E-03**
Biogenic Carbon Emission from Packaging	kg CO_2	0	0	9.88E-03	0	0	0	0	0	0	0	0	0	0	0	**9.88E-03**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination Carbon Emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation Carbon Removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

5.2 Life cycle impact assessment (LCIA)

It shall be reiterated at this point that the reported impact categories represent impact potentials; they are approximations of environmental impacts that could occur if the emitted molecules would follow the underlying impact pathway and meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen functional unit (relative approach). LCIA results are therefore relative expressions only and do not predict actual impacts on category endpoints, the exceeding of thresholds, safety margins, or risks.

Life cycle impact assessment (LCIA) results are shown for Knauf's insulation products. Unlike life cycle inventories, which only report sums for individual inventory flows, the LCIA includes a classification of individual emissions with regard to the impacts they are associated with and subsequently a characterization of the emissions by a factor expressing their respective contribution to the impact category indicator. The end result is a single metric for quantifying each potential impact, such as "Global Warming Potential".

The impact assessment results are calculated using characterization factors published by the United States Environmental Protection Agency. The TRACI 2.1 (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts 2.1) methodology is the most widely applied impact assessment method for U.S. LCA studies. The SM2013 Methodology is also applied to come up with single score results.

The six impact categories required by the PCR are globally deemed mature enough to be included in Type III environmental declarations. Other categories are being developed and defined and LCA should continue making advances in their development; however, the EPD users shall not use additional measures for comparative purposes. Impact categories which were not required by the PCR are included in part to allow for the calculation of millipoints using the SM2013 Methodology, but it should be noted that there are known limitations related to these impact categories due to their high degree of uncertainty.

5.2.1. EcoBatt® Insulation

Tables 5.2.1a-d show the contributions of each stage of the life cycle for the average of the four options for EcoBatt® Insulation: unfaced, kraft-faced, foil-faced, and FSK-faced.

For the unfaced product, the manufacturing stage dominates the results for all impact categories except for respiratory effects, where the raw material acquisition stage dominates. Following these two stages, the next highest impacts come from transportation and disposal, which have a similar contribution. The impact of the raw material acquisition stage is mostly due to the batch and binder materials. Since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables below are likely much larger than the actual impacts in the raw material acquisition stage. The energy required to melt the glass and produce the glass fibers is the largest contributor to the manufacturing stage. The contributions to outbound transportation are casued by the use of trucks and rail transport. The landfilling of the discarded product contributes to the disposal stage. The only impacts associated with installation and maintenance are due to the disposal of packaging waste, which is the smallest contributor of all the stages.

Borax, manganese oxide, and soda ash are the main contributors to the batch impacts, and dextrose is the main contributor to the binder impacts. Raw material inbound transportation is a small contributor to the impacts for this stage.

For the faced products, the raw material acquisition stage is higher compared to the unfaced products because it includes potential impacts from the facing. There is also a small increase in the contributions to transportation and disposal due to the increased mass of the product due to the addition of the facing.

Table 5.2.1a Unfaced EcoBatt® Insulation impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	2.94E-03	1.11E-04	3.86E-06	0	0	0	0	0	0	0	0	1.63E-05	0	4.77E-05	**3.12E-03**
Eutrophication	kg N eq	2.20E-04	6.92E-06	8.72E-07	0	0	0	0	0	0	0	0	3.26E-06	0	5.80E-06	**2.37E-04**
Global warming	kg CO_2 eq	6.09E-01	8.12E-02	5.70E-04	0	0	0	0	0	0	0	0	4.34E-03	0	1.19E-02	**7.07E-01**
Ozone depletion	kg CFC-11 eq	1.32E-10	2.80E-12	3.60E-11	0	0	0	0	0	0	0	0	2.62E-13	0	1.62E-12	**1.73E-10**
Carcinogenics	CTUh	7.20E-11	1.43E-13	1.53E-13	0	0	0	0	0	0	0	0	9.02E-15	0	2.03E-13	**7.25E-11**
Non-carcinogenics	CTUh	1.90E-12	5.20E-14	1.67E-13	0	0	0	0	0	0	0	0	3.78E-16	0	1.30E-14	**2.13E-12**
Respiratory effects	kg PM2.5 eq	9.10E-04	6.76E-06	4.57E-07	0	0	0	0	0	0	0	0	1.24E-06	0	4.97E-05	**9.68E-04**
Smog	kg O_3 eq	2.23E-02	1.91E-03	2.63E-05	0	0	0	0	0	0	0	0	3.64E-04	0	6.37E-04	**2.52E-02**
Ecotoxicity	CTUe	1.80E-04	4.32E-05	1.36E-07	0	0	0	0	0	0	0	0	1.93E-06	0	3.72E-06	**2.29E-04**
Fossil fuel depletion	MJ, LHV	7.56E-01	1.64E-01	3.36E-04	0	0	0	0	0	0	0	0	8.26E-03	0	2.39E-02	**9.52E-01**

Table 5.2.1b Kraft-faced EcoBatt® Insulation impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	3.32E-03	1.41E-04	3.86E-06	0	0	0	0	0	0	0	0	6.16E-05	0	1.81E-04	**3.71E-03**
Eutrophication	kg N eq	3.10E-04	8.77E-06	8.72E-07	0	0	0	0	0	0	0	0	6.85E-06	0	1.22E-05	**3.38E-04**
Global warming	kg CO_2 eq	6.97E-01	1.03E-01	5.70E-04	0	0	0	0	0	0	0	0	1.92E-02	0	5.24E-02	**8.72E-01**
Ozone depletion	kg CFC-11 eq	2.08E-10	3.55E-12	3.60E-11	0	0	0	0	0	0	0	0	3.33E-13	0	2.06E-12	**2.50E-10**
Carcinogenics	CTUh	7.54E-11	1.81E-13	1.53E-13	0	0	0	0	0	0	0	0	2.59E-13	0	5.82E-12	**8.18E-11**
Non-carcinogenics	CTUh	2.10E-12	6.59E-14	1.67E-13	0	0	0	0	0	0	0	0	9.80E-14	0	3.38E-12	**5.80E-12**
Respiratory effects	kg PM2.5 eq	9.62E-04	8.57E-06	4.57E-07	0	0	0	0	0	0	0	0	1.68E-06	0	6.69E-05	**1.04E-03**
Smog	kg O_3 eq	2.89E-02	2.42E-03	2.63E-05	0	0	0	0	0	0	0	0	6.73E-04	0	1.18E-03	**3.32E-02**
Ecotoxicity	CTUe	2.52E-04	5.47E-05	1.36E-07	0	0	0	0	0	0	0	0	3.40E-06	0	6.54E-06	**3.17E-04**
Fossil fuel depletion	MJ, LHV	1.09E+00	2.07E-01	3.36E-04	0	0	0	0	0	0	0	0	1.05E-02	0	3.03E-02	**1.34E+00**

Table 5.2.1c Foil-faced EcoBatt® Insulation impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	3.08E-03	1.51E-04	3.86E-06	0	0	0	0	0	0	0	0	2.21E-05	0	6.50E-05	**3.33E-03**
Eutrophication	kg N eq	3.27E-04	9.43E-06	8.72E-07	0	0	0	0	0	0	0	0	4.44E-06	0	7.90E-06	**3.49E-04**
Global warming	kg CO_2 eq	9.48E-01	1.11E-01	5.70E-04	0	0	0	0	0	0	0	0	5.92E-03	0	1.62E-02	**1.08E+00**
Ozone depletion	kg CFC-11 eq	2.83E-09	3.82E-12	3.60E-11	0	0	0	0	0	0	0	0	3.57E-13	0	2.21E-12	**2.87E-09**
Carcinogenics	CTUh	3.47E-10	1.94E-13	1.53E-13	0	0	0	0	0	0	0	0	1.23E-14	0	2.76E-13	**3.48E-10**
Non-carcinogenics	CTUh	2.38E-08	7.09E-14	1.67E-13	0	0	0	0	0	0	0	0	5.14E-16	0	1.77E-14	**2.38E-08**
Respiratory effects	kg PM2.5 eq	1.06E-03	9.21E-06	4.57E-07	0	0	0	0	0	0	0	0	1.70E-06	0	6.76E-05	**1.14E-03**
Smog	kg O_3 eq	4.03E-02	2.60E-03	2.63E-05	0	0	0	0	0	0	0	0	4.96E-04	0	8.67E-04	**4.43E-02**
Ecotoxicity	CTUe	2.57E-02	5.88E-05	1.36E-07	0	0	0	0	0	0	0	0	2.63E-06	0	5.07E-06	**2.58E-02**
Fossil fuel depletion	MJ, LHV	1.72E+00	2.23E-01	3.36E-04	0	0	0	0	0	0	0	0	1.13E-02	0	3.25E-02	**1.99E+00**

Table 5.2.1d FSK-faced EcoBatt® Insulation impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	4.39E-03	1.57E-04	3.86E-06	0	0	0	0	0	0	0	0	2.29E-05	0	6.72E-05	**4.64E-03**
Eutrophication	kg N eq	3.43E-04	9.75E-06	8.72E-07	0	0	0	0	0	0	0	0	4.59E-06	0	8.17E-06	**3.67E-04**
Global warming	kg CO_2 eq	9.89E-01	1.14E-01	5.70E-04	0	0	0	0	0	0	0	0	6.12E-03	0	1.67E-02	**1.13E+00**
Ozone depletion	kg CFC-11 eq	3.27E-09	3.95E-12	3.60E-11	0	0	0	0	0	0	0	0	3.69E-13	0	2.28E-12	**3.31E-09**
Carcinogenics	CTUh	4.87E-10	2.01E-13	1.53E-13	0	0	0	0	0	0	0	0	1.27E-14	0	2.86E-13	**4.88E-10**
Non-carcinogenics	CTUh	3.99E-08	7.33E-14	1.67E-13	0	0	0	0	0	0	0	0	5.32E-16	0	1.83E-14	**3.99E-08**
Respiratory effects	kg PM2.5 eq	1.13E-03	9.53E-06	4.57E-07	0	0	0	0	0	0	0	0	1.75E-06	0	7.00E-05	**1.21E-03**
Smog	kg O_3 eq	4.30E-02	2.69E-03	2.63E-05	0	0	0	0	0	0	0	0	5.13E-04	0	8.97E-04	**4.72E-02**
Ecotoxicity	CTUe	2.76E-02	6.08E-05	1.36E-07	0	0	0	0	0	0	0	0	2.72E-06	0	5.24E-06	**2.77E-02**
Fossil fuel depletion	MJ, LHV	1.79E+00	2.31E-01	3.36E-04	0	0	0	0	0	0	0	0	1.16E-02	0	3.36E-02	**2.07E+00**

Variations

The four different facing options impact the type and amount of raw materials extracted during the raw material acquisition stage. When facing is added, the increased mass of the product causes a higher transportation impact. There is also an increased impact during disposal due to the different facing materials being landfilled.

Single score results

The SM millipoint score by life cycle phase for this product is presented below (Table 5.2.1e). They conflict with the trends in the results using the impact assessment results before normalization and weighting. Due to the normalization and weighting required to create single score results, different stages can dominate the characterized and single score results. The batch ingredients sand and borax contribute significantly to the respiratory effects category, causing the raw materials acquisition stage to dominate the mPt results, but not the characterized results. However, since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables below are likely much larger than the actual impacts in the raw material acquisition stage. What this means is that the manufacturing stage may have a larger share of the impact than what is displayed in the total impacts by life cycle stage.

Table 5.2.1e Averaged SM millipoint scores for EcoBatt® Insulation by life cycle stage per functional unit [5]

Impact category	Unit	Raw material acquisition	Manufacturing	Transportation	Installation and maintenance	Disposal/reuse/ recycling	Total
		A1-A2	A3	A4	A5, B1-B7	C1-C4	
SM single figure score	mPts	**5.34E-02**	**8.21E-03**	**8.53E-04**	**2.82E-05**	**3.90E-03**	**6.64E-02**

Numbers shown in **purple** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

5.2.2. Jet Stream® Ultra and EcoFill™ Wx Blowing Wool Insulation

Table 5.2.2a shows the contributions of each stage of the life cycle for Jet Stream® Ultra and EcoFill™ Wx Blowing Wool Insulation.

The manufacturing stage dominates the results for all impact categories except for respiratory effects, where the raw materials acquisition stage dominates. Following these two stages, the next highest impacts come from transportation and disposal, which have a similar contribution. However, for non-carcinogenics, the installation and maintenance stage is the second highest contributor due to packaging disposal. The impact of the raw material acquistion stage is mostly due to the borax, manganese oxide, and soda ash in the batch. Since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. Quicklime production is associated with global warming impacts due to carbon dioxide emissions from its manufacturing process. The manufacturing stage shows major contributions to all impact categories. The contributions to outbound transportation are casued by the use of trucks and rail transport. The landfilling of the discarded product contributes to the disposal stage. The only impacts associated with installation and maintenance are due to the disposal of packaging waste, which is the smallest contributor of all the stages except for non-carcinogenics.

The energy required to melt the glass and produce the glass fibers is the largest contributor to the manufacturing stage for all impact categories.

Table 5.2.2a Jet Stream® Ultra and EcoFill™ Wx Blowing Wool Insulation impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	1.95E-03	4.48E-05	2.93E-05	0	0	0	0	0	0	0	0	1.78E-05	0	5.21E-05	**2.10E-03**
Eutrophication	kg N eq	1.22E-04	2.85E-06	1.61E-06	0	0	0	0	0	0	0	0	3.56E-06	0	6.34E-06	**1.36E-04**
Global warming	kg CO_2 eq	7.30E-01	3.50E-02	1.61E-02	0	0	0	0	0	0	0	0	4.75E-03	0	1.30E-02	**7.99E-01**
Ozone depletion	kg CFC-11 eq	1.67E-10	1.03E-12	4.00E-09	0	0	0	0	0	0	0	0	2.86E-13	0	1.77E-12	**4.17E-09**
Carcinogenics	CTUh	2.98E-11	4.89E-14	3.18E-13	0	0	0	0	0	0	0	0	9.86E-15	0	2.22E-13	**3.04E-11**
Non-carcinogenics	CTUh	1.56E-12	2.17E-14	2.11E-13	0	0	0	0	0	0	0	0	4.13E-16	0	1.42E-14	**1.80E-12**
Respiratory effects	kg PM2.5 eq	9.61E-04	2.77E-06	1.75E-06	0	0	0	0	0	0	0	0	1.36E-06	0	5.43E-05	**1.02E-03**
Smog	kg O_3 eq	2.50E-02	7.47E-04	2.58E-04	0	0	0	0	0	0	0	0	3.98E-04	0	6.96E-04	**2.71E-02**
Ecotoxicity	CTUe	1.01E-04	1.88E-05	5.14E-07	0	0	0	0	0	0	0	0	2.11E-06	0	4.07E-06	**1.26E-04**
Fossil fuel depletion	MJ, LHV	9.60E-01	7.12E-02	3.44E-03	0	0	0	0	0	0	0	0	9.03E-03	0	2.61E-02	**1.07E+00**

Variations

There are no variations between Jet Stream® Ultra and EcoFill™ Wx Blowing Wool Insulation.

Single score results

The SM millipoint score by life cycle phase for this product is presented below (Table 5.2.2b). They conflict with the trends in the results using the impact assessment results before normalization and weighting. Due to the normalization and weighting required to create single score results, different stages can dominate the characterized and single score results. The batch ingredients sand and borax contribute significantly to the respiratory effects category, causing the raw materials acquisition stage to dominate the mPt results, but not the characterized results. However, since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. What this means is that the manufacturing stage may have a larger share of the impact than what is displayed in the total impacts by life cycle stage.

Table 5.2.2b SM millipoint scores for Jet Stream® Ultra and EcoFill™ Wx Blowing Wool Insulation by life cycle stage per functional unit [5]

Impact category	**Unit**	Raw material acquisition	Manufacturing	Transportation	Installation and maintenance	Disposal/reuse/ recycling	**Total**
		A1-A2	A3	A4	A5, B1-B7	C1-C4	
SM single figure score	mPts	5.02E-02	7.29E-03	2.79E-04	1.55E-04	3.24E-03	**6.11E-02**

5.2.3. JetSpray™ Thermal Insulation

Table 5.2.3a shows the contributions of each stage of the life cycle for JetSpray™ Thermal Insulation.

The manufacturing stage dominates the results for the acidification, global warming, ozone depletion, carcinogens, smog, and fossil fuel depletion impact categories. The remaining impact categories are dominated by the raw materials acquisition stage. Following these two stages, the next highest impacts come from transportation and disposal, which have a similar contribution. However, for ozone depletion, carcinogenics, and non-carcinogenics, the installation and maintenance stage is the third highest contributor due to packaging disposal. The impact of the raw material acquistion stage is mostly due to the borax, manganese oxide, and soda ash in the batch and the dextrose in the binder. Since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. Quicklime production is associated with global warming impacts due to carbon dioxide emissions from its manufacturing process. The manufacturing stage shows major contributions to all impact categories. The contributions to outbound transportation are casued by the use of trucks and rail transport. The landfilling of the discarded product contributes to the disposal stage. The only impacts associated with installation and maintenance are due to the disposal of packaging waste, which is the smallest contributor of all the stages except for ozone depletion, carcinogenics, and non-carcinogenics.

The energy required to melt the glass and produce the glass fibers is the largest contributor to the manufacturing stage for all impact categories.

Table 5.2.3a JetSpray™ Thermal Insulation impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	5.28E-03	1.20E-04	7.82E-05	0	0	0	0	0	0	0	0	4.75E-05	0	1.39E-04	**5.66E-03**
Eutrophication	kg N eq	4.25E-04	7.61E-06	4.29E-06	0	0	0	0	0	0	0	0	9.52E-06	0	1.69E-05	**4.63E-04**
Global warming	kg CO_2 eq	1.93E+00	9.36E-02	4.30E-02	0	0	0	0	0	0	0	0	1.27E-02	0	3.47E-02	**2.12E+00**
Ozone depletion	kg CFC-11 eq	4.46E-10	2.74E-12	1.07E-08	0	0	0	0	0	0	0	0	7.65E-13	0	4.73E-12	**1.11E-08**
Carcinogenics	CTUh	9.77E-11	1.31E-13	8.48E-13	0	0	0	0	0	0	0	0	2.63E-14	0	5.92E-13	**9.93E-11**
Non-carcinogenics	CTUh	5.74E-10	5.80E-14	5.63E-13	0	0	0	0	0	0	0	0	1.10E-15	0	3.80E-14	**5.75E-10**
Respiratory effects	kg PM2.5 eq	2.52E-03	7.39E-06	4.69E-06	0	0	0	0	0	0	0	0	3.63E-06	0	1.45E-04	**2.68E-03**
Smog	kg O_3 eq	6.77E-02	2.00E-03	6.88E-04	0	0	0	0	0	0	0	0	1.06E-03	0	1.86E-03	**7.33E-02**
Ecotoxicity	CTUe	8.79E-03	5.02E-05	1.37E-06	0	0	0	0	0	0	0	0	5.64E-06	0	1.09E-05	**8.86E-03**
Fossil fuel depletion	MJ, LHV	2.61E+00	1.90E-01	9.18E-03	0	0	0	0	0	0	0	0	2.41E-02	0	6.97E-02	**2.90E+00**

Variations

There are no variations.

Single score results

The SM millipoint score by life cycle phase for this product is presented below (Table 5.2.3b). They conflict with the trends in the results using the impact assessment results before normalization and weighting. Due to the normalization and weighting required to create single score results, different stages can dominate the characterized and single score results. The batch ingredients sand and borax contribute significantly to the respiratory effects category, causing the raw materials acquisition stage to dominate the mPt results, but not the characterized results. However, since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. What this means is that the manufacturing stage may have a larger share of the impact than what is displayed in the total impacts by life cycle stage.

Table 5.2.3b SM millipoint scores for JetSpray™ Thermal Insulation by life cycle stage per functional unit [5]

Impact category	**Unit**	Raw material acquisition	Manufacturing	Transportation	Installation and maintenance	Disposal/reuse/ recycling	**Total**
		A1-A2	A3	A4	A5, B1-B7	C1-C4	
SM single figure score	mPts	1.31E-01	1.95E-02	7.45E-04	4.14E-04	8.66E-03	**1.61E-01**

5.2.4. Atmosphere™ Duct Liner & Wall and Ceiling Liner M (and AKOUSTI-LINER™ and AKOUSTI-SHIELD™)

Table 5.2.4a shows the contributions of each stage of the life cycle for Atmosphere™ Duct Liner & Wall and Ceiling Liner M (and AKOUSTI-LINER™ and AKOUSTI-SHIELD™).

The manufacturing stage dominates the results for the acidification, global warming, ozone depletion, smog, ecotoxicity, and fossil fuel depletion impact categories. The remaining impact categories are dominated by the raw materials acquisition stage. Following these two stages, the next highest impacts come from transportation and disposal, which have a similar contribution. However, for smog, the transportation stage is the second highest contributor due to the use of trucks and rail transport. The impact of the raw material acquistion stage is mostly due to the borax, manganese dioxide, and soda ash in the batch and the dextrose in the binder. Since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. The manufacturing stage shows major contributions to all impact categories. The landfilling of the discarded product contributes to the disposal stage. The only impacts associated with installation and maintenance are due to the disposal of packaging waste, which is the smallest contributor of all the stages.

The energy required to melt the glass and produce the glass fibers is the largest contributor to the manufacturing stage for all impact categories.

Table 5.2.4a Atmosphere™ Duct Liner & Wall and Ceiling Liner M (and AKOUSTI-LINER™ and AKOUSTI-SHIELD™) impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	6.76E-03	1.04E-03	1.86E-05	0	0	0	0	0	0	0	0	6.46E-05	0	1.90E-04	**8.08E-03**
Eutrophication	kg N eq	5.49E-04	8.33E-05	4.62E-06	0	0	0	0	0	0	0	0	5.41E-06	0	9.62E-06	**6.52E-04**
Global warming	kg CO_2 eq	2.26E+00	1.95E-01	3.19E-02	0	0	0	0	0	0	0	0	1.49E-02	0	4.06E-02	**2.54E+00**
Ozone depletion	kg CFC-11 eq	7.94E-10	1.34E-12	1.92E-11	0	0	0	0	0	0	0	0	1.02E-13	0	6.34E-13	**8.16E-10**
Carcinogenics	CTUh	2.27E-09	1.03E-10	8.49E-12	0	0	0	0	0	0	0	0	7.86E-12	0	1.77E-10	**2.57E-09**
Non-carcinogenics	CTUh	2.46E-07	7.67E-09	1.06E-09	0	0	0	0	0	0	0	0	5.85E-10	0	2.01E-08	**2.75E-07**
Respiratory effects	kg PM2.5 eq	2.19E-03	5.43E-05	1.32E-05	0	0	0	0	0	0	0	0	3.41E-06	0	1.36E-04	**2.40E-03**
Smog	kg O_3 eq	7.73E-02	3.49E-02	3.87E-04	0	0	0	0	0	0	0	0	2.14E-03	0	3.74E-03	**1.18E-01**
Ecotoxicity	CTUe	2.15E-01	2.43E-02	3.53E-04	0	0	0	0	0	0	0	0	1.85E-03	0	3.57E-03	**2.45E-01**
Fossil fuel depletion	MJ, LHV	2.89E+00	3.70E-01	6.47E-03	0	0	0	0	0	0	0	0	2.82E-02	0	8.14E-02	**3.38E+00**

Variations

There are no variations between Atmosphere™ Duct Liner & Wall and Ceiling Liner M (and AKOUSTI-LINER™ and AKOUSTI-SHIELD™).

Single score results

The SM millipoint score by life cycle phase for this product is presented below (Table 5.2.4b). They conflict with the trends in the results using the impact assessment results before normalization and weighting. Due to the normalization and weighting required to create single score results, different stages can dominate the characterized and single score results. The batch ingredients sand and borax contribute significantly to the respiratory effects category, causing the raw materials acquisition stage to dominate the mPt results, but not the characterized results. However, since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. What this means is that the manufacturing stage may have a larger share of the impact than what is displayed in the total impacts by life cycle stage.

Table 5.2.4b SM millipoint scores for Atmosphere™ Duct Liner & Wall and Ceiling Liner M (and AKOUSTI-LINER™ and AKOUSTI-SHIELD™) by life cycle stage per functional unit [5]

Impact category	**Unit**	Raw material acquisition	Manufacturing	Transportation	Installation and maintenance	Disposal/reuse/ recycling	**Total**
		A1-A2	A3	A4	A5, B1-B7	C1-C4	
SM single figure score	mPts	8.97E-02	4.38E-02	3.93E-03	8.67E-04	8.23E-03	**1.47E-01**

5.2.5. Atmosphere™ Duct Wrap (and ALLEY WRAP™ B) and KN Utility Insulation

Tables 5.2.5a-b show the contributions of each stage of the life cycle for the two options for Atmosphere™ Duct Wrap and ALLEY WRAP™ B (unfaced and FSK-faced) and KN Utility Insulation.

For the unfaced product, the manufacturing stage dominates the results for all impact categories except for eutrophication and respiratory effects, where the raw materials acquisition stage dominates. Following these two stages, the next highest impacts come from transportation and disposal, which have a similar contribution. However, for non-carcinogenics, the disposal stage is the second highest contributor due to the landfilling of the product at end of life, and for smog, the transportation is the second highest contributor due to the use of trucks and rail transport. The impact of the raw material acquistion stage is mostly due to the borax and soda ash in the batch. Since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. The manufacturing stage shows major contributions to all impact categories. The landfilling of the discarded product contributes to the disposal stage. The only impacts associated with installation and maintenance are due to the disposal of packaging waste, which is the smallest contributor of all the stages.

The energy required to melt the glass and produce the glass fibers is the largest contributor to the manufacturing stage for all impact categories.

For the faced product, the raw material acquisition stage is higher compared to the unfaced products because it includes potential impacts from the facing. There is also a small increase in the contributions to transportation and disposal due to the increased mass of the product due to the addition of the facing.

Table 5.2.5a Unfaced Atmosphere™ Duct Wrap (and ALLEY WRAP™ B) and KN Utility Insulation impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	7.19E-03	1.24E-03	3.32E-05	0	0	0	0	0	0	0	0	7.31E-05	0	2.15E-04	**8.74E-03**
Eutrophication	kg N eq	6.12E-04	9.87E-05	8.35E-06	0	0	0	0	0	0	0	0	6.12E-06	0	1.09E-05	**7.36E-04**
Global warming	kg CO_2 eq	7.88E+00	2.31E-01	5.02E-02	0	0	0	0	0	0	0	0	1.68E-02	0	4.59E-02	**8.22E+00**
Ozone depletion	kg CFC-11 eq	8.45E-10	1.59E-12	5.65E-11	0	0	0	0	0	0	0	0	1.16E-13	0	7.17E-13	**9.04E-10**
Carcinogenics	CTUh	5.61E-10	1.22E-10	1.89E-11	0	0	0	0	0	0	0	0	8.90E-12	0	2.00E-10	**9.11E-10**
Non-carcinogenics	CTUh	3.61E-08	9.08E-09	2.57E-09	0	0	0	0	0	0	0	0	6.62E-10	0	2.28E-08	**7.12E-08**
Respiratory effects	kg PM2.5 eq	2.93E-03	6.44E-05	2.91E-05	0	0	0	0	0	0	0	0	3.86E-06	0	1.54E-04	**3.19E-03**
Smog	kg O_3 eq	1.00E-01	4.14E-02	7.46E-04	0	0	0	0	0	0	0	0	2.42E-03	0	4.23E-03	**1.49E-01**
Ecotoxicity	CTUe	1.38E-01	2.88E-02	9.06E-04	0	0	0	0	0	0	0	0	2.10E-03	0	4.04E-03	**1.74E-01**
Fossil fuel depletion	MJ, LHV	3.85E+00	4.38E-01	1.44E-02	0	0	0	0	0	0	0	0	3.19E-02	0	9.21E-02	**4.43E+00**

Table 5.2.5b FSK-faced Atmosphere™ Duct Wrap (and ALLEY WRAP™ B) impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	8.63E-03	1.49E-03	3.32E-05	0	0	0	0	0	0	0	0	8.83E-05	0	2.59E-04	**1.05E-02**
Eutrophication	kg N eq	7.35E-04	1.19E-04	8.35E-06	0	0	0	0	0	0	0	0	7.39E-06	0	1.31E-05	**8.83E-04**
Global warming	kg CO_2 eq	8.26E+00	2.79E-01	5.02E-02	0	0	0	0	0	0	0	0	2.03E-02	0	5.55E-02	**8.66E+00**
Ozone depletion	kg CFC-11 eq	3.98E-09	1.92E-12	5.65E-11	0	0	0	0	0	0	0	0	1.40E-13	0	8.65E-13	**4.04E-09**
Carcinogenics	CTUh	9.77E-10	1.47E-10	1.89E-11	0	0	0	0	0	0	0	0	1.07E-11	0	2.42E-10	**1.40E-09**
Non-carcinogenics	CTUh	7.59E-08	1.10E-08	2.57E-09	0	0	0	0	0	0	0	0	7.99E-10	0	2.75E-08	**1.18E-07**
Respiratory effects	kg PM2.5 eq	3.16E-03	7.77E-05	2.91E-05	0	0	0	0	0	0	0	0	4.66E-06	0	1.86E-04	**3.45E-03**
Smog	kg O_3 eq	1.21E-01	4.99E-02	7.46E-04	0	0	0	0	0	0	0	0	2.92E-03	0	5.11E-03	**1.79E-01**
Ecotoxicity	CTUe	1.65E-01	3.47E-02	9.06E-04	0	0	0	0	0	0	0	0	2.53E-03	0	4.88E-03	**2.09E-01**
Fossil fuel depletion	MJ, LHV	4.89E+00	5.28E-01	1.44E-02	0	0	0	0	0	0	0	0	3.85E-02	0	1.11E-01	**5.58E+00**

Variations

KN Utility Insulation is an unfaced product, while Atmosphere™ Duct Wrap and ALLEY WRAP™ B have the option of coming unfaced or with FSK facing. When FSK facing is added, there is an increased amount and different types of raw materials which impacts the raw material acquisition stage. The increased mass of the product with FSK facing causes a slightly higher transportation impact. There is also an increased impact during disposal due to the FSK facing materials being landfilled.

Single score results

The SM millipoint scores by life cycle phase for these products are presented below (Tables 5.2.5c-d). They conflict with the trends in the results using the impact assessment results before normalization and weighting. Due to the normalization and weighting required to create single score results, different stages can dominate the characterized and single score results. The batch ingredients sand and borax contribute significantly to the respiratory effects category, causing the raw materials acquisition stage to dominate the mPt results, but not the characterized results. However, since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. What this means is that the manufacturing stage may have a larger share of the impact than what is displayed in the total impacts by life cycle stage.

Table 5.2.5c Averaged SM millipoint scores for Atmosphere™ Duct Wrap and KN Utility Insulation by life cycle stage per functional unit [5]

Impact category	Unit	Raw material acquisition	Manufacturing	Transportation	Installation and maintenance	Disposal/reuse/ recycling	Total
		A1-A2	A3	A4	A5, B1-B7	C1-C4	
SM single figure score	mPts	1.32E-01	6.81E-02	5.02E-03	1.84E-03	1.00E-02	**2.17E-01**

Numbers shown in **purple** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

Table 5.2.5d Averaged SM millipoint scores for unfaced and FSK-faced ALLEY WRAP™ B by life cycle stage per functional unit [5]

Impact category	Unit	Raw material acquisition	Manufacturing	Transportation	Installation and maintenance	Disposal/reuse/ recycling	Total
		A1-A2	A3	A4	A5, B1-B7	C1-C4	
SM single figure score	mPts	1.34E-01	6.81E-02	5.18E-03	1.84E-03	1.04E-02	**2.20E-01**

Numbers shown in **purple** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

5.2.6. Akousti-Board Black™

Table 5.2.7a shows the contributions of each stage of the life cycle for Akousti-Board Black™.

The manufacturing stage dominates the results for all impact categories except for eutrophication and respiratory effects, and non-carcinogenics. The raw materials acquisition stage dominates the results for eutrophication and respiratory effects, and the disposal stage dominates the results for non-carcinogenics. The impact of the raw material acquistion stage is mostly due to the borax, manganese dioxide, and soda ash in the batch and the dextrose in the binder. Since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. The manufacturing stage shows major contributions to all impact categories. For smog and ecotoxcity, the transportation stage was the second highest contributor to the results; the contributions to outbound transportation are casued by the use of trucks and rail transport. For carcinogenics, the disposal stage was the second highest contributor to the results; the landfilling of the discarded product contributes to the disposal stage. The only impacts associated with installation and maintenance are due to the disposal of packaging waste, which is the smallest contributor to the results.

The energy required to melt the glass and produce the glass fibers is the largest contributor to the manufacturing stage for all impact categories.

Table 5.2.7a Akousti-Board Black™ impact potential results per functional unit [5]

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	Total
Acidification	kg SO_2 eq	2.59E-02	4.80E-03	3.43E-05	0	0	0	0	0	0	0	0	3.07E-04	0	9.00E-04	**3.20E-02**
Eutrophication	kg N eq	2.12E-03	3.84E-04	8.53E-06	0	0	0	0	0	0	0	0	2.57E-05	0	4.57E-05	**2.59E-03**
Global warming	kg CO_2 eq	9.21E+00	8.97E-01	5.78E-02	0	0	0	0	0	0	0	0	7.05E-02	0	1.93E-01	**1.04E+01**
Ozone depletion	kg CFC-11 eq	3.55E-09	6.19E-12	3.85E-11	0	0	0	0	0	0	0	0	4.86E-13	0	3.01E-12	**3.60E-09**
Carcinogenics	CTUh	1.78E-09	4.75E-10	1.62E-11	0	0	0	0	0	0	0	0	3.73E-11	0	8.40E-10	**3.15E-09**

Non-carcinogenics	CTUh	1.09E-07	3.53E-08	2.04E-09	0	0	0	0	0	0	0	0	2.78E-09	0	9.56E-08	**2.45E-07**
Respiratory effects	kg PM2.5 eq	9.88E-03	2.50E-04	2.51E-05	0	0	0	0	0	0	0	0	1.62E-05	0	6.47E-04	**1.08E-02**
Smog	kg O_3 eq	3.07E-01	1.61E-01	7.20E-04	0	0	0	0	0	0	0	0	1.01E-02	0	1.78E-02	**4.97E-01**
Ecotoxicity	CTUe	3.04E-01	1.12E-01	6.89E-04	0	0	0	0	0	0	0	0	8.79E-03	0	1.69E-02	**4.42E-01**
Fossil fuel depletion	MJ, LHV	1.02E+01	1.70E+00	1.23E-02	0	0	0	0	0	0	0	0	1.34E-01	0	3.87E-01	**1.24E+01**

Variations

There are no variations.

Single score results

The SM millipoint score by life cycle phase for this product is presented below (Table 5.2.7b). They conflict with the trends in the results using the impact assessment results before normalization and weighting. Due to the normalization and weighting required to create single score results, different stages can dominate the characterized and single score results. The batch ingredients sand and borax contribute significantly to the respiratory effects category, causing the raw materials acquisition stage to dominate the mPt results, but not the characterized results. However, since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. What this means is that the manufacturing stage may have a larger share of the impact than what is displayed in the total impacts by life cycle stage.

Table 5.2.7b SM millipoint scores for Akousti-Board Black™ by life cycle stage per functional unit [5]

Impact category	**Unit**	Raw material acquisition	Manufacturing	Transportation	Installation and maintenance	Disposal/reuse/ recycling	**Total**
		A1-A2	A3	A4	A5, B1-B7	C1-C4	
SM single figure score	mPts	4.07E-01	1.90E-01	1.81E-02	1.64E-03	3.91E-02	**6.55E-01**

5.2.7. Black Acoustical Board and Acoustical Smooth Board

Table 5.2.8a shows the contributions of each stage of the life cycle for the average of Black Acoustical Board and Acoustical Smooth Board.

The manufacturing stage dominates the results for all impact categories except for eutrophication, respiratory effects, and non-carcinogenics. The raw materials acquisition stage dominates the results for eutrophication and respiratory effects, and the disposal stage dominates the results for non-carcinogenics. The impact of the raw material acquistion stage is mostly due to the borax, manganese dioxide, and soda ash in the batch and the dextrose in the binder. Since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. The manufacturing stage shows major contributions to all impact categories. For smog and ecotoxcity, the transportation stage was the second highest contributor to the results; the contributions to outbound transportation are casued by the use of trucks and rail transport. For carcinogenics, the disposal stage was the second highest contributor to the results; the landfilling of the discarded product contributes to the disposal stage. The only impacts associated with installation and maintenance are due to the disposal of packaging waste, which is the smallest contributor to the results.

The energy required to melt the glass and produce the glass fibers is the largest contributor to the manufacturing stage for all impact categories.

Table 5.2.8a Average Black Acoustical Board and Acoustical Smooth Board impact potential results per functional unit [5]

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	Total
Acidification	kg SO_2 eq	2.58E-02	4.71E-03	3.43E-05	0	0	0	0	0	0	0	0	3.01E-04	0	8.83E-04	**3.18E-02**
Eutrophication	kg N eq	2.12E-03	3.76E-04	8.53E-06	0	0	0	0	0	0	0	0	2.52E-05	0	7.00E-05	**2.60E-03**
Global warming	kg CO_2 eq	9.16E+00	8.80E-01	5.78E-02	0	0	0	0	0	0	0	0	6.92E-02	0	2.58E-01	**1.04E+01**
Ozone depletion	kg CFC-11 eq	3.55E-09	6.07E-12	3.85E-11	0	0	0	0	0	0	0	0	4.77E-13	0	3.43E-12	**3.60E-09**
Carcinogenics	CTUh	1.76E-09	4.66E-10	1.62E-11	0	0	0	0	0	0	0	0	3.66E-11	0	8.61E-10	**3.14E-09**
Non-carcinogenics	CTUh	1.08E-07	3.47E-08	2.04E-09	0	0	0	0	0	0	0	0	2.72E-09	0	9.66E-08	**2.44E-07**
Respiratory effects	kg PM2.5 eq	9.87E-03	2.46E-04	2.51E-05	0	0	0	0	0	0	0	0	1.59E-05	0	6.51E-04	**1.08E-02**
Smog	kg O_3 eq	3.06E-01	1.58E-01	7.20E-04	0	0	0	0	0	0	0	0	9.96E-03	0	2.74E-02	**5.01E-01**
Ecotoxicity	CTUe	3.00E-01	1.10E-01	6.89E-04	0	0	0	0	0	0	0	0	8.63E-03	0	2.53E-02	**4.44E-01**
Fossil fuel depletion	MJ, LHV	1.00E+01	1.67E+00	1.23E-02	0	0	0	0	0	0	0	0	1.31E-01	0	5.11E-01	**1.23E+01**

Numbers shown in **purple** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

Variations

The deviation between these two products is the addition of a black mat layer on the Black Acoustical Board. However, there is no significant impact on any of the impact categories due to this deviation.

Single score results

The SM millipoint score by life cycle phase for this product is presented below (Table 5.2.8b). They conflict with the trends in the results using the impact assessment results before normalization and weighting. Due to the normalization and weighting required to create single score results, different stages can dominate the characterized and single score results. The batch ingredients sand and borax contribute significantly to the respiratory effects category, causing the raw materials acquisition stage to dominate the mPt results, but not the characterized results. However, since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. What this means is that the manufacturing stage may have a larger share of the impact than what is displayed in the total impacts by life cycle stage.

Table 5.2.8b Averaged SM millipoint scores for Black Acoustical Board and Acoustical Smooth Board by life cycle stage per functional unit [5]

Impact category	Unit	Raw material acquisition	Manufacturing	Transportation	Installation and maintenance	Disposal/reuse/ recycling	Total
		A1-A2	A3	A4	A5, B1-B7	C1-C4	
SM single figure score	mPts	**4.06E-01**	**1.90E-01**	**1.78E-02**	**1.64E-03**	**3.83E-02**	**6.55E-01**

Numbers shown in **purple** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

5.2.8. Earthwool® Insulation Board (and AK BOARD™)

Tables 5.2.9a-c shows the contributions of each stage of the life cycle for the three options for Earthwool® Insulation Board (and AK BOARD™): unfaced, FSK-faced, and ASJ+-faced.

For the unfaced product, the manufacturing stage dominates the results for all impact categories except for eutrophication, respiratory effects, and non-carcinogenics. The raw materials acquisition stage dominates the results for eutrophication and respiratory effects, and the disposal stage dominates the results for non-carcinogenics. The impact of the raw material acquistion stage is mostly due to the borax, manganese dioxide, and soda ash in the batch and the dextrose in the binder. Since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. The manufacturing stage shows major contributions to all impact categories. The contributions to outbound transportation are casued by the use of trucks and rail transport. The landfilling of the discarded product contributes to the disposal stage. The only impacts associated with installation and maintenance are due to the disposal of packaging waste, which is the smallest contributor to the results.

The energy required to melt the glass and produce the glass fibers is the largest contributor to the manufacturing stage for all impact categories.

For the faced products, the raw material acquisition stage is higher compared to the unfaced products because it includes potential impacts from the facing. There is also a small increase in the contributions to transportation and disposal due to the increased mass of the product due to the addition of the facing.

Table 5.2.9a Unfaced Earthwool® Insulation Board (and AK BOARD™) impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	2.57E-02	4.62E-03	3.43E-05	0	0	0	0	0	0	0	0	2.95E-04	0	8.66E-04	**3.16E-02**
Eutrophication	kg N eq	2.11E-03	3.69E-04	8.53E-06	0	0	0	0	0	0	0	0	2.47E-05	0	4.39E-05	**2.55E-03**
Global warming	kg CO_2 eq	9.11E+00	8.63E-01	5.78E-02	0	0	0	0	0	0	0	0	6.78E-02	0	1.85E-01	**1.03E+01**
Ozone depletion	kg CFC-11 eq	3.55E-09	5.95E-12	3.85E-11	0	0	0	0	0	0	0	0	4.68E-13	0	2.89E-12	**3.59E-09**
Carcinogenics	CTUh	1.74E-09	4.57E-10	1.62E-11	0	0	0	0	0	0	0	0	3.59E-11	0	8.08E-10	**3.05E-09**
Non-carcinogenics	CTUh	1.07E-07	3.40E-08	2.04E-09	0	0	0	0	0	0	0	0	2.67E-09	0	9.20E-08	**2.38E-07**
Respiratory effects	kg PM2.5 eq	9.85E-03	2.41E-04	2.51E-05	0	0	0	0	0	0	0	0	1.56E-05	0	6.22E-04	**1.08E-02**
Smog	kg O_3 eq	3.04E-01	1.55E-01	7.20E-04	0	0	0	0	0	0	0	0	9.76E-03	0	1.71E-02	**4.86E-01**
Ecotoxicity	CTUe	2.95E-01	1.08E-01	6.89E-04	0	0	0	0	0	0	0	0	8.46E-03	0	1.63E-02	**4.29E-01**
Fossil fuel depletion	MJ, LHV	9.87E+00	1.64E+00	1.23E-02	0	0	0	0	0	0	0	0	1.29E-01	0	3.72E-01	**1.20E+01**

Table 5.2.9b FSK-faced Earthwool® Insulation Board (and AK BOARD™) impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	2.72E-02	4.83E-03	3.43E-05	0	0	0	0	0	0	0	0	3.09E-04	0	9.05E-04	**3.33E-02**
Eutrophication	kg N eq	2.23E-03	3.86E-04	8.53E-06	0	0	0	0	0	0	0	0	2.58E-05	0	4.60E-05	**2.70E-03**
Global warming	kg CO_2 eq	9.49E+00	9.03E-01	5.78E-02	0	0	0	0	0	0	0	0	7.09E-02	0	1.94E-01	**1.07E+01**
Ozone depletion	kg CFC-11 eq	6.68E-09	6.22E-12	3.85E-11	0	0	0	0	0	0	0	0	4.89E-13	0	3.03E-12	**6.73E-09**

Carcinogenics	CTUh	2.15E-09	4.78E-10	1.62E-11	0	0	0	0	0	0	0	0	3.75E-11	0	8.45E-10	**3.53E-09**
Non-carcinogenics	CTUh	1.47E-07	3.55E-08	2.04E-09	0	0	0	0	0	0	0	0	2.79E-09	0	9.62E-08	**2.83E-07**
Respiratory effects	kg PM2.5 eq	1.01E-02	2.52E-04	2.51E-05	0	0	0	0	0	0	0	0	1.63E-05	0	6.51E-04	**1.10E-02**
Smog	kg O_3 eq	3.24E-01	1.62E-01	7.20E-04	0	0	0	0	0	0	0	0	1.02E-02	0	1.79E-02	**5.15E-01**
Ecotoxicity	CTUe	3.23E-01	1.13E-01	6.89E-04	0	0	0	0	0	0	0	0	8.85E-03	0	1.71E-02	**4.62E-01**
Fossil fuel depletion	MJ, LHV	1.09E+01	1.71E+00	1.23E-02	0	0	0	0	0	0	0	0	1.35E-01	0	3.89E-01	**1.31E+01**

Table 5.2.9c ASJ+-faced Earthwool® Insulation Board (and AK BOARD™) impact potential results per functional unit [5]

Impact category	**Unit**	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	**Total**
Acidification	kg SO_2 eq	2.76E-02	4.94E-03	3.43E-05	0	0	0	0	0	0	0	0	3.16E-04	0	9.26E-04	**3.38E-02**
Eutrophication	kg N eq	2.27E-03	3.95E-04	8.53E-06	0	0	0	0	0	0	0	0	2.64E-05	0	4.70E-05	**2.75E-03**
Global warming	kg CO_2 eq	9.69E+00	9.24E-01	5.78E-02	0	0	0	0	0	0	0	0	7.26E-02	0	1.98E-01	**1.09E+01**
Ozone depletion	kg CFC-11 eq	7.14E-09	6.37E-12	3.85E-11	0	0	0	0	0	0	0	0	5.01E-13	0	3.10E-12	**7.19E-09**
Carcinogenics	CTUh	2.39E-09	4.89E-10	1.62E-11	0	0	0	0	0	0	0	0	3.84E-11	0	8.64E-10	**3.80E-09**
Non-carcinogenics	CTUh	1.70E-07	3.63E-08	2.04E-09	0	0	0	0	0	0	0	0	2.86E-09	0	9.85E-08	**3.10E-07**
Respiratory effects	kg PM2.5 eq	1.01E-02	2.58E-04	2.51E-05	0	0	0	0	0	0	0	0	1.67E-05	0	6.66E-04	**1.11E-02**
Smog	kg O_3 eq	3.32E-01	1.66E-01	7.20E-04	0	0	0	0	0	0	0	0	1.04E-02	0	1.83E-02	**5.27E-01**
Ecotoxicity	CTUe	3.42E-01	1.15E-01	6.89E-04	0	0	0	0	0	0	0	0	9.05E-03	0	1.74E-02	**4.84E-01**
Fossil fuel depletion	MJ, LHV	1.16E+01	1.75E+00	1.23E-02	0	0	0	0	0	0	0	0	1.38E-01	0	3.98E-01	**1.39E+01**

Variations

The three different facing options impact the type and amount of raw materials extracted during the raw material acquisition stage. The addition of facing contributes to higher impacts.

Single score results

The SM millipoint score by life cycle phase for this product is presented below (Table 5.2.9d). They conflict with the trends in the results using the impact assessment results before normalization and weighting. Due to the normalization and weighting required to create single score results, different stages can dominate the characterized and single score results. The batch ingredients sand and borax contribute significantly to the respiratory effects category, causing the raw materials acquisition stage to dominate the mPt results, but not the characterized results. However, since sand and borax are melted in the oven with the other batch materials, they are not released into the air as fine particulates. Therefore, the calculated potential impacts as shown in the results tables are likely much larger than the actual impacts in the raw material acquisition stage. What this means is that the manufacturing stage may have a larger share of the impact than what is displayed in the total impacts by life cycle stage.

Table 5.2.9d Averaged SM millipoint scores for Earthwool® Insulation Board (and AK BOARD™) by life cycle stage per functional unit [5]

Impact category	**Unit**	Raw material acquisition	Manufacturing	Transportation	Installation and maintenance	Disposal/reuse/ recycling	**Total**
		A1-A2	A3	A4	A5, B1-B7	C1-C4	
SM single figure score	mPts	**4.16E-01**	**1.90E-01**	**1.81E-02**	**1.64E-03**	**3.91E-02**	**6.65E-01**

Numbers shown in **purple** have a variation of 10 to 20%

Numbers shown in **red** have a variation greater than 20%

5.3 Sensitivity analysis

A sensitivity analysis is performed for raw material percentages and SM single figure scores using the highest and lowest values for the most important choices and assumptions to check the robustness of the results of the LCA (disregarding outliers is appropriate). Identifying which choices or assumption influence the results in any environmental parameter by more than 20% shall be reported. The previous section includes the variations within the product groups which are dominated by the product composition, transportation phase, and end of life phase as indicated.

5.4 Overview of relevant findings

This study assessed a multitude of inventory and environmental indicators. The overall results are consistent with expectations for insulation products' life cycles, as these products are not associated with energy consumption during their use stage. The primary finding, across the environmental indicators and for the products considered, was that manufacturing dominates the impacts due to the energy required to melt the glass and produce the glass fibers.

Raw materials production also accounts for a relevant contribution to impact across all inventory and impact indicators. Borax, manganese oxide, and soda ash are the three main contributors for the insulation products studied.

While facing is one of the larger contributions to raw material acquisition impacts, it is important to keep in mind that the fiberglass to facing mass ratio is typically higher for actual products than it is for the functional unit in this analysis. When fiberglass insulation is sold, its R-value is typically higher than R_{SI} = 1. Therefore, facing will represent a smaller fraction of total product impact for actual fiberglass insulation products. The binder and facing in particular are key contributors to both renewable primary energy demand and eutrophication due to their use of renewable materials.

Only for the global warming and smog formation impact categories does outbound transport account for a sizable impact. For other impact categories, outbound transport is a minor contributor. The impact associated with outbound transport is consistently higher than that for inbound transport due to the further transportation distances as well as lower capacity utilization rates.

Installation accounts for a small fraction of overall life cycle impact given that batts and rolls are often manually installed. The only installation impacts are associated with packaging disposal. There is no impact associated with the use stage. While insulation can influence building energy performance, this aspect is assumed to be 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. No replacements are necessary; therefore, results represent the production of one square meter of insulation at a thickness defined by the functional unit.

At the end of life, insulation is removed from the building and landfilled. Any carbon in the dextrose from the binder is assumed to be sequestered. For all products, waste was dominated by the final disposal of the product. Non-hazardous waste also accounts for waste generated during manufacturing and installation. No hazardous waste is created by the product system.

5.5 Discussion on data quality

Inventory data quality is judged by its precision (measured, calculated or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied on a study serving as a data source), and representativeness (geographical, temporal, and technological).

To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the GaBi LCI databases were used. The LCI datasets from the GaBi 2017 databases are widely distributed and used with the GaBi 7 Software. In the process of providing these datasets they are cross-checked with other databases and values from industry and science.

Precision and completeness

- Precision: As the relevant foreground data is primary data or modeled based on primary information sources of the owner of the technology, precision is considered to be high. Seasonal variations were balanced out by collecting 12 months of data. All background data are from GaBi databases with the documented precision.
- Completeness: Each unit process was checked for mass balance and completeness of the emission inventory. Capital equipment was excluded under cut-off criteria. Otherwise, no data were knowingly omitted.

Consistency and reproducibility

- Consistency: To ensure consistency, all primary data were collected with the same level of detail, while all background data were sourced from the GaBi databases. Allocation and other methodological choices were made consistently throughout the model.
- Reproducibility: Reproducibility is warranted as much as possible through the disclosure of input-output data, dataset choices, and modeling approaches in this report. Based on this information, any third party should be able to approximate the results of this study using the same data and modeling approaches.

Representativeness

- Temporal: All primary data were collected for October 2015 through September 2016 in order to ensure representativeness of post-consumer content. All secondary data were obtained from the GaBi 2017 databases and are typically representative of the years 2011 – 2016.
- Geographical: Primary data are representative of Knauf's production in the US. Data were collected mainly from the Shelbyville facility, but were also collected at Lanett and Shasta Lake for the wrap products. Differences in electric grid mix are taken into account with appropriate secondary data. In general, secondary data were collected specific to the country under study. Where country-specific data were unavailable, proxy data were used. Geographical representativeness is considered to be high.
- Technological: All primary and secondary data were modeled to be specific to the technologies under study. Technological representativeness is considered to be high.

5.6 Completeness, sensitivity, and consistency

Completeness
All relevant process steps for each product system were considered and modeled to represent each specific situation. The process chain is considered sufficiently complete with regard to the goal and scope of this study.

Sensitivity
Sensitivity analyses were performed to test the robustness of the results towards uncertainty, as described earlier in this report.

Consistency
All assumption, methods, and data were found to be consistent with the study's goal and scope. Differences in background data quality were minimized by using LCI data from the GaBi 2017 databases. System boundaries, allocation rules, and impact assessment methods have been applied consistently throughout the study.

5.7 Conclusions, limitations, and recommendations

The goal of this study was to conduct a cradle-to grave LCA on several insulation products so as to develop SM Transparency Reports. The creation of these Transparency Reports will allow consumers in the building and construction industry to make better informed decisions about the environmental impacts associated with the products they choose. Overall, the study found that environmental performance is driven primarily by cradle-to-gate impact. Manufacturing emissions and energy consumption drive environmental performance. Additionally, raw materials also account for a notable contribution to impact. The gate-to-grave stages account for minimal contribution to life cycle performance.

It should be noted that the contribution to impact results associated with facing is high relative to the contribution of fiberglass due to the PCR's "artificial" functional unit of R_{SI} = 1. Fiberglass insulation used in practice is associated with a higher fiberglass-to-facing mass ratio and thus a smaller relative contribution from the facing itself. This study did not consider the energy savings associated with the use of insulation in a building. It is expected that these savings, compared to a building that does not use insulation, would far outweigh the impacts attributed to the manufacturing, transportation, and installation of the product.

The results show that the largest area for reduction of each product's environmental impact is in the manufacturing phase. This is an important area for Knauf to focus its efforts and one which it can influence.

6 SOURCES

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ACRONYMS

GaBi	Ganzheitliche Bilanzierung (German for holistic balancing)
ISO	International Standardization Organization
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact analysis
PCR	Product Category Rule document
PE	PE International (now thinkstep)
TR	Transparency Report™
ts	thinkstep
ULE	UL Environment

GLOSSARY

For the purposes of this report, the terms and definitions given in ISO 14020, ISO 14025, the ISO 14040 series, and ISO 21930 apply. The most important ones are included here:

allocation	Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems
close loop & open loop	A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials. An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties.
cradle to grave	Addresses the environmental aspects and potential environmental impacts (e.g. use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition until the end of life
cradle to gate	Addresses the environmental aspects and potential environmental impacts (e.g. use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition until the end of the production process ("gate of the factory"). It may also include transportation until use phase
declared unit	quantity of a product for use as a reference unit in an EPD based on one or more information modules
functional unit	quantified performance of a product system for use as a reference unit
life cycle	consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal
life cycle assessment - LCA	compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle
life cycle impact assessment - LCIA	phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product

life cycle inventory - LCI phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle

life cycle interpretation Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations

APPENDIX A. USED DATASHEETS

To model the LCA different data sources have been used. This appendix includes a list of all datasheets that have been used:

- LCA results – Batts and rolls_2018
- LCA results – Board products_2018
- LCA results – Duct wrap_2018
- LCA results – Liner_2018
- LCA results – Loosefill_2018
- Primary data_Board products
- Primary data_Duct wrap
- Primary data_Duct+WC liner
- Primary data_Facers
- Primary data_JetSpray adhesive