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**LIFE CYCLE ASSESSMENT (LCA)  
OF AFT LOOSEFILL CELLULOSE INSULATION  
PRODUCTS**

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Status Final

Client AFT



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# 1 INTRODUCTION

## 1.1 Opportunity

Advanced Fiber Technology (AFT) is a manufacturer of cellulose insulation dedicated to ensuring the highest quality products and standards [1]. In fulfilling their commitment to sustainability, it is important for AFT to conduct a product specific Life Cycle Assessment. The Life Cycle Assessment will evaluate the environmental impacts of conventional loose-fill cellulose insulation in all life cycle stages, from raw materials to manufacturing and through to the end of life. The goal of creating this product specific Life Cycle Assessment is to discover the full range of environmental impacts the product has and to review these impacts along with product specific Environmental Product Declarations in order to find ways to improve processes and reduce overall impacts. This project is important to AFT's commitment to provide information to the market to assess the environmental impacts of products and solutions.

To understand the complete impact of this product through all life cycle stages, AFT has decided to use a cradle-to-grave approach in conducting the Life Cycle Assessment. By taking all stages into account a more comprehensive study of the product is created.

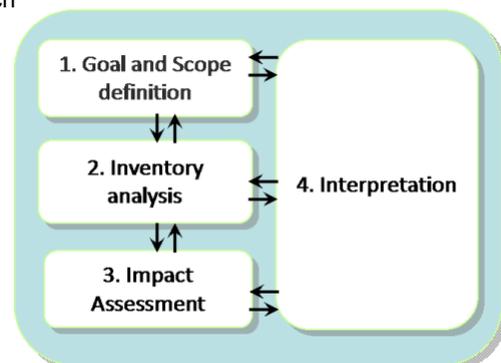
AFT is interested in having a Life Cycle Assessment (LCA) conducted on conventional loose-fill cellulose insulation, so that they can have the data available to the public within a Sustainable Minds Transparency Report™. A Sustainable Minds Transparency Report™ is a Type III Environmental Declaration 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. This study aims at being compliant to the requirements of ISO14040/14044 standards.

AFT commissioned Sustainable Minds to develop an LCA for a typical loose-fill cellulose insulation product manufactured by AFT. AFT wants to be able to compare this product to the industry-wide LCA

## 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 A3 and Part B2 format to conform to EN 15804 and ISO 21930:2017 [2]. This report includes the following phases:

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



Source: ISO 14040

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. The LCA does follow an attributional approach as outlined in ISO 21930 Section 7.1.1.

### 1.3 Status

All information in this report reflects the best possible inventory by AFT at the time it was collected, and best practices were conducted by Sustainable Minds and AFT employees to transform this information into this LCA report. The data covers annual manufacturing data for 1/2018-12/2018 from AFT.

Where data was missing, assumptions were made from manufacturing data based upon expertise from the respective manufacturers' employees.

The data from the manufacturer represents one manufacturing location: Bucyrus, OH

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

AFT 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 on behalf of AFT:

- Doug Leuthold, President at AFT

Doug has been assisted by numerous AFT during the data collection, reporting, and interpretation phases.

From Sustainable Minds:

- Manuela Toro, LCA Practitioner
- Milla Marcano, LCA Project Manager

### 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

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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 the AFT conventional loose-fill cellulose insulation product. It is intended for both internal and external purposes; business to business 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 AFT involved in marketing and communications, operations, and design. This study is not intended for the purpose of comparative assertions. Supplemental studies with participating manufacturers may involve comparative assertions. 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

AFT is a manufacturer of cellulose insulation as a segment of the thermal / acoustical insulation industry. As an organization, AFT is interested in demonstrating its sustainability leadership. It is also interested in leveraging business value associated with transparent reporting of conventional loose-fill cellulose insulation's cradle-to-grave environmental impacts. For more information on AFT products, go to <https://www.advanced-fiber.com/>

Conventional loose-fill cellulose insulation is made from any cellular plant source although it typically comes from waste paper products. It is installed by using an insulation blowing machine. Conventional loose-fill cellulose insulation is typically applied to enclosed areas, unfinished attic floors, and other hard to reach places. The function of insulation is to help keep your home's interior at the desired temperature while reducing the amount of energy used and reduce noise transmission.

The product studied in this report is listed in Table 2.2a with the company name and the manufacturing location. Declaration name with product represented and type of declaration for the product is listed in Table 2.2b.

**Table 2.2a** Manufacturing location

Company	Product name	Manufacturing location(s)
AFT	AFT Loose Fill	Bucyrus, OH

**Table 2.2b** Product specific declaration name with products represented and type of declaration

Transparency Report name	Manufacturer name	Product name(s)	Type of declaration
Conventional Loose-fill Cellulose Insulation	AFT	AFT Loose Fill	Product specific

Conventional loose-fill cellulose insulation falls under CSI 07 21 60. The legal requirement for cellulose insulation is Consumer Products Safety Commission interim safety standard 16 CFR Part 1209. Conventional loose-fill cellulose insulated is applied using insulation blowing machines that move the material into walls or attics.

## 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 [2], the functional unit is:

1 m<sup>2</sup> of installed insulation material with a thickness that gives an average thermal resistance  $R_{SI} = 1 \text{ m}^2\text{-K/W}$  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 [2]. Therefore, the insulation does not need to be replaced, and 1 m<sup>2</sup> of insulation plus 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  $R_{SI} = 1 \text{ m}^2\text{-K/W}$ , which varies for each product. Reference flows are listed in Table 2.2c.

**Table 2.2c** Reference flows

Manufacturer	Product	Cellulose (kg)	Packaging (kg)	Thickness at $R_{SI}=1$ (m)	Reference flow total (kg)
AFT	AFT Loose Fill	.6089	.0609	.0381	.960

## 2.4 System boundaries

This section describes the system boundaries for the products.

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:

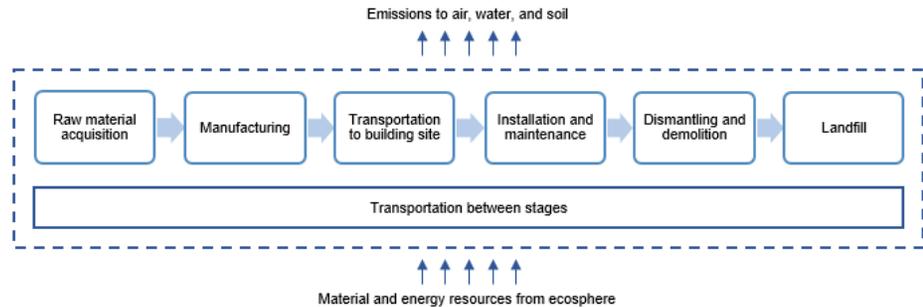
- Raw materials acquisition, transportation, and manufacturing
- Distribution and installation

- Use
- 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 PCR [2].

The system boundaries for the AFT products are detailed below.

Figure 2.4a represents the life cycle stages for the entire life cycle of this product. Table 2.4a lists specific inclusions and exclusions for the system boundaries.



**Figure 2.4a** Applied system boundaries for the modeled insulation product

**Table 2.4a** System boundaries

Included	Excluded
<ul style="list-style-type: none"> <li>• Raw material acquisition and processing</li> <li>• Processing of materials</li> <li>• Energy production</li> <li>• Transport of raw materials</li> <li>• Outbound transportation of products</li> <li>• Overhead energy (heating, lighting, forming, finishing, etc.) of manufacturing facilities</li> <li>• Packaging of final products</li> <li>• Installation and maintenance, including material loss, energy use, and auxiliary material requirements</li> <li>• End-of-life, including transportation</li> </ul>	<ul style="list-style-type: none"> <li>• Construction of major capital equipment</li> <li>• Maintenance and operation of support equipment</li> <li>• Human labor and employee transport</li> <li>• Manufacture and transport of packaging materials not associated with final product</li> <li>• Disposal of packaging materials not associated with final product</li> <li>• Building operational energy and water use</li> </ul>

#### 2.4.1. A1-A3: Raw materials acquisition, transportation, and manufacturing

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

##### Raw materials (RM) acquisition and transportation (A1-A2)

The RM acquisition and transportation stage includes, where relevant, the following processes:

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

##### 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

#### **2.4.2. A4-A5: Distribution and installation**

##### **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

##### **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.
- 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

#### **2.4.3. B1-B7: Use**

The use stage includes:

- Product use
- Maintenance
- Repair
- Replacement
- Refurbishment
- Operational energy use
- Operational water use

#### **2.4.4. C1-C4: Disposal/reuse/recycling**

##### **Deconstruction (C1)**

The deconstruction stage includes dismantling/demolition.

##### **Transport (C2)**

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

##### **Waste processing (C3)**

The waste processing stage includes processing required before final disposition.

##### **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 [3] [4].

### 3.1 Data collection

Data used for this project represents a mix of primary data collected from AFT on the production of the insulation products (gate-to-gate) and background data from ecoinvent 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 AFT.
- **Background data:** All data from ecoinvent 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. Table 3.4.2 shows the datasets that were chosen from ecoinvent. Detailed database documentation for ecoinvent can be accessed at: <https://www.ecoinvent.org/database/database.html>.

All primary data were provided by AFT on detailed data collection form; energy data provided come from utility bills. 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 AFT to resolve any open issues.

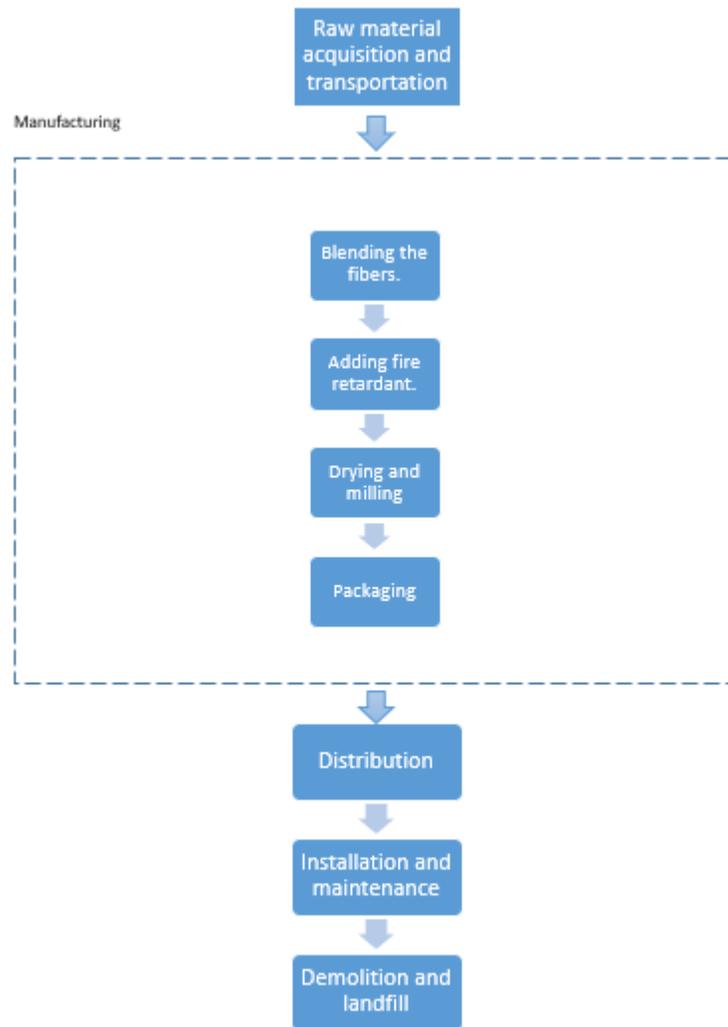
### 3.2 Primary data

Conventional loose-fill cellulose insulation is produced in several manufacturing steps that involve the blending of fibers, adding the fire retardant in liquid form to the fibers, and then drying and milling the fibers before placing them into bags.

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 conventional loose-fill cellulose insulation.

Data used in this analysis represent insulation production at the AFT manufacturer. Results were then scaled to reflect the functional unit; The facility inputs and outputs were input into SimaPro to get raw results. The raw results were then multiplied by the mass

per functional unit and divided by mass per year. This is how the calculations were allocated to the product level.



**Figure 3.2a** Life cycle flow chart of insulation product production

### 3.2.1. Raw materials acquisition and transportation (A1-A2)

Raw materials acquisition and transportation represents the first stage of the insulation product life cycle. Fire retardants, adhesives, fiber sources, and other raw materials are transported to AFT manufacturing facility.

Mixed papers, boric acid, mineral oil and other raw materials are transported to the manufacturing facility. Raw material inputs for the products are listed in Tables 3.2a-m. Since mixed papers, waste papers, and newspapers are secondary materials, they are assumed to arrive at the facilities burden-free aside from the transportation necessary to deliver them. Secondary materials have already gone through processing and manufacturing stages earlier in their life, the use of them in insulation does not require these steps. Only transportation phases are included, because it is the only phase to be considered for use of secondary materials.

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 [5].

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 AFT's facility via truck. AFT has one manufacturing facility to which the raw materials are shipped. Transport data were collected and shown in Tables 3.2a. Mass percentage is the percent composition of each material based on weight of total mass of the product; the percent mass was calculated for each material input for AFT.

**Table 3.2a** AFT raw material inputs

Flow	Mass percentage	Transportation mode	Distance (km)
████	████	Truck	1184.47
████	████	Truck and trailer	667.88
████	████	Truck and trailer	856.17
████	████	Truck and trailer	144.84
████	████	Truck and trailer	360.49
████	████	Tanker truck	204.39
████	████	Truck and trailer	241.4
████	████	Truck and trailer	143.23
████	████		
████	████	Truck and trailer	241.4
████	████	Truck and trailer	856.17
████	████	Truck and trailer	144.84
████	████	Truck and trailer	360.49

### 3.2.2. Manufacturing (A3)

After the raw materials are transported to AFT's facility, the newspaper and other fiber raw material inputs are shredded and considered to be wastepaper. Fire retardants and other chemicals are then added including dust suppressants to reduce dust formed. The material is then transformed into fibers through fiberization, packaged, and shipped to the distributor or building site.

Annual manufacturing inputs and outputs for the products are shown in Table 3.2.2a. Emissions associated with the production of electricity and gasoline are accounted for in the ecoinvent background processes. Dust emissions are accounted for.

**Table 3.2.2a** AFT annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity (NERC)	████	kWh
	Oil/grease	████	kg

Outputs	Packaged product	████	kg
	Empty packaging	████	kg
	Wastepaper wires (raw material packaging)	████	kg
	Unusable wastepaper	████	kg
	Dust	████	kg

Annual manufacturing inputs and outputs were provided by AFT; annual inputs and outputs are data collected by the manufacturer and provided to LCA practitioner.

### 3.2.3. Distribution (A4)

Products are packaged in the manufacturing plant and shipped directly to distributors, dealers, and showrooms for purchase by the end users in the US. Table 3.2.3 details insulation distribution. The distribution data was provided directly from the AFT: this distances to the distributors were confirmed by AFT.

**Table 3.2.3** Distribution assumptions for cellulose insulation products

Parameter	Value	Unit
Vehicle Type	Truck and trailer 20 ton	
Fuel Type	Diesel	
Truck transport distance		
AFT	482.8	km

### 3.2.4. Installation (A5)

At the installation site, insulation products are unpackaged and installed with a blowing machine. The potential impacts from use of the blower is included in this study. 90% of blowers use gasoline while 10% use electricity as stated by a AFT [5]. Based on data given by the amount of electricity and gasoline used in installation by blowers annually was modeled and is shown in Table 3.2.4a. Data is input into SimaPro and after results are acquired, there is allocation with functional unit.

**Table 3.2.4a** Gas and electricity used annually for installation

Application	Electricity (kWh)	Gasoline (kg)
Insulation blower	406	11,973

Plastic insulation packaging is assumed to be thrown away into landfill after installation. 100% of the packaging is assumed to be landfilled.

### 3.2.5. Use (B1-B7)

Based on UL PCR, 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. There are no operational energy or water use aspects to the use of this product.

### **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)**

After removal, the insulation is assumed to be transported 161 kilometers to the disposal site to be landfilled for AFT. This distance was assumed because it was the farthest distance provided to a landfill and therefore the most conservative assumption; this assumption is based on the industry average EPD. Truck and trailer transport using diesel fuel is used.

### **3.2.8. Waste processing (C3)**

No waste processing is required before being landfilled.

### **3.2.9. Disposal (C4)**

After removal, the insulation is assumed to be landfilled. Since removal is typically associated with demolition or remodeling activities, the insulation is not assumed to be reused or recycled. 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.
- Data based on material and energy flows were used.
- 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.
- Any missing data was confirmed to the manufacturer and was treated using assumptions, averages and datasets. Data regarding transportation during A4 was taken as an average- this is based on the industry average data.

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 January 2018 to December 2018. These dates were chosen in order to capture a representative picture of loose-fill cellulose insulation manufacturing by AFT. Background data for upstream and downstream processes (i.e. raw materials, energy resources, transportation, and ancillary materials) were obtained from the ecoinvent and NERC databases.

**Technology coverage.** Data were collected for loose-fill cellulose insulation production at AFT facilities in the US.

**Geographical coverage.** AFT has one facility in the United States. As such, the geographical coverage for this study is based on North American system boundaries for all processes and products. Whenever US background data were not readily available, European data or global data were used as proxies. Following production, insulation is shipped for use within North America. 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 eGrid NERC database. Medium voltage electricity data set was used. Table 3.4.1 shows all the 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, medium voltage {RFC}  market for   APOS, U	NERC	2014	US RFC
Electricity	Electricity, medium voltage {SERC}  market for   APOS, U	NERC	2014	US SERC
Oil	Lubricating oil {GLO}  market for   APOS, U	Ecoinvent	2014	Global
Gasoline	Gasoline, combusted in equipment/US	Ecoinvent	2014	US

#### 3.4.2 Raw materials production

Data for up- and down-stream raw materials were obtained from the ecoinvent databases. Table 3.4.3 shows all the LCI datasets used in modeling the raw materials.

**Table 3.4.2** Key material datasets used in inventory analysis

Raw material	Dataset name	Primary source	Reference year	Geography
Product	Boric acid, anhydrous, powder {GLO}  market for   APOS, U	EI v3	2014	Global
Product	Ammonium sulfate, as N {GLO}  market for   APOS, U	EI v3	2014	Global
Product	Chemical, organic	EI v3	2014	Global
Product	Chemical, inorganic	EI v3	2014	Global
Product	Maize starch, {GLO}  market for   APOS, U	EI v3	2014	Global
Product	White mineral oil, at plant NREL/RNA U	EI 2.2	2008	North America
Product	Water, ultrapure {GLO}  market for   APOS, U	EI v3	2014	Global
Product	Zinc {GLO}  market for   APOS, U	EI v3	2014	Global
Packaging	Packaging film, low density polyethylene {GLO}  market for   APOS, U	EI v3	2014	Global
Packaging	Kraft paper, unbleached {GLO}  market for   APOS, U	EI v3	2014	Global
Packaging	Steel low-alloyed {GLO}  market for   APOS, U	EI v3	2014	Global

### 3.4.3. Transportation

Transportation distances and modes of transport are included for the transport of the raw materials to production facility. Typical vehicles used include truck and trailers.

**Table 3.4.4** Key transportation datasets used in inventory analysis

Transportation	Dataset name	Primary source	Reference year	Geography
Truck and trailer 20 ton	Transport, freight, lorry 16-32 ton, euro6 {RER}   market for APOS, U	EI v3	2018	Global
Tanker truck, 6,500 gallon	Transport, freight, lorry 16-32 ton, euro6 {RER}   market for APOS, U	EI v3	2018	Global
Truck and trailer	Transport, freight, lorry 16-32 ton, euro6 {RER}   market for APOS, U	EI v3	2018	Global
Truck	Transport, freight, lorry 16-32 ton, euro6 {RER}   market for APOS, U	EI v3	2018	Global
Truck and trailer, 16 ton	Transport, freight, lorry 16-32 ton, euro6 {RER}   market for APOS, U	EI v3	2018	Global

### 3.4.4. Disposal

Disposal processes were obtained from the ecoinvent databases for packaging materials, dust of paper/cellulose fines, and unusable fiber. The 'Inert waste, for final

disposal' data set was used for the packaging material. Table 3.4.5 reviews the relevant disposal dataset used in the model.

**Table 3.4.4** Key disposal datasets used in inventory analysis

Material disposed	Dataset name	Primary source	Year	Geography
Wire ties	Inert waste, for final disposal {GLO}  market for   APOS, U	EI v3	2014	Global
Other	Inert waste, for final disposal {GLO}  market for   APOS, U	EI v3	2014	Global
Shrink/plastic wrap	Inert waste, for final disposal {GLO}  market for   APOS, U	EI v3	2014	Global
Unusable fiber	Inert waste, for final disposal {GLO}  market for   APOS, U	EI v3	2014	Global
Cellulose fines	Inert waste, for final disposal {GLO}  market for   APOS, U	EI v3	2014	Global
Dust of paper	Inert waste, for final disposal {GLO}  market for   APOS, U	EI v3	2014	Global
Non toxic waste	Inert waste, for final disposal {GLO}  market for   APOS, U	EI v3	2014	Global
Empty packaging	Inert waste, for final disposal {GLO}  market for   APOS, U	EI v3	2014	Global
Plastic bag	Inert waste, for final disposal {GLO}  market for   APOS, U	EI v3	2014	Global
PE film	Inert waste, for final disposal {GLO}  market for   APOS, U	EI v3	2014	Global
Product	Inert waste, for final disposal {GLO}  market for   APOS, U	EI v3	2014	Global

### 3.4.5. Emissions to air, water, and soil

All gate-to-gate emissions reported by AFT for the manufacturing stage are taken into account in the study. Emissions measured and reported by AFT are detailed under primary data collection. Dust emission in this study is displayed in Table 3.4.5.

**Table 3.4.5** Key emission data set used in the inventory analysis

Emission	Dataset name	Primary source	Reference year
Dust	Dust (unspecified)	ecoinvent	2018

Data for all upstream materials, electricity, and energy carriers were obtained from the ecoinvent databases. The emissions due to the use of electricity are accounted for within the database processes. Likewise, emissions from gasoline are accounted for within the database process. Emissions associated with transportation were determined by capturing the logistical operations.

### 3.5 Limitations

Loose-fill cellulose insulation is assumed to have a reference service life equal to that of the building [5]. 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  $R_{SI} = 1 \text{ m}^2 \cdot \text{K}/\text{W}$  [2], it should be noted that a product with this R-value is not sold by AFT. The declared product is delivered to the site of installation with the R-value chosen by the customer.

Proxy data used in the LCA model were limited to background data for raw material production. Proxy data for water and dust was used. Global data was used for this study, because AFT specific results have been taken from an industry-wide LCA. North American background data were used whenever possible.

### 3.6 Criteria for the exclusion of inputs and outputs

All energy and material flow data were included in the model and comply with the UL PCR cut-off criteria. None of the data that was provided needed to be excluded by the cut-off rules [2].

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.
- Assumptions included were made about which datasets were the best fitting. Based on data given from manufacturers, LCA practitioner chose best fitting datasets in ecoinvent based on material type and location.
- Assumptions regarding A4 transportation distances were made, the farthest distance was assumed so to obtain most conservative results.
- 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.

### **3.7 Allocation**

Whenever a system boundary is crossed, environmental inputs and outputs have to be assigned to the different products. The PCRs prescribe to report where and how allocation occurs in the modeling of the LCA.

AFT has provided data for one product and one facility. Annual facility data and annual insulation production volumes, specific to this product, were used to determine manufacturing inputs and emissions.

### **3.8 Software and database**

The LCA model was created using SimaPro Analyst 9.0.0.49 for life cycle engineering<sup>14</sup>. The ecoinvent<sup>13</sup> LCI data sets from version numbers listed in section 3.4 provide the life cycle inventory data of all the raw materials and processes for modeling the product.

### **3.9 Critical review**

This is a supporting LCA report for an AFT product specific loose-fill cellulose insulation Transparency Report and will be evaluated for conformance to the PCRs according to ISO 14025 [6] and the ISO 14040/14044 standards [7].

## 4 IMPACT ASSESSMENT METHODS

### 4.1 Impact assessment

The environmental indicators as required by the PCR are included as well as other indicators required to use the SM2013 Methodology [16] (see Table 4.1). The impact indicators are derived using the 100-year time horizon<sup>1</sup> factors, where relevant, as defined by TRACI 2.1 classification and characterization [9]. 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 <sub>2</sub> eq (sulphur dioxide)
Ecotoxicity	CTUe
Eutrophication	kg N eq (nitrogen)
Global warming	kg CO <sub>2</sub> eq (carbon dioxide)
Ozone depletion	kg CFC-11 eq
Carcinogenics	CTUh
Non-carcinogenics	CTUh
Respiratory effects	kg PM <sub>2.5</sub> eq (fine particulates)
Smog	kg O <sub>3</sub> eq (ozone)
Fossil fuel depletion	MJ surplus

With respect to global warming potential, biogenic carbon is accounted for in this study and reported separately as indicated by the PCR.

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.

The TRACI results were not normalized or weighted in this study.

### 4.2 Normalization and weighting

To arrive to a single score indicator, normalization [10] and weighting [11] conforming to the SM2013 Methodology were applied.

<sup>1</sup> 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.

Single figure scores make it easier for non-LCA experts to understand the meaning of LCA results. While having indicator results stated by individual impact categories enables LCA experts to make impact comparisons between products on a granular level, single figure scores assist the non-LCA expert to understand the relative environmental performance either when evaluating products in a purchasing process or developing product concepts in the design process. Limitations to single-score results are that they add an additional level of uncertainty that comes along with transformation of the score. According to ISO “it should be recognized that there is no scientific basis for reducing LCA results to a single overall score or number.”

Only single figure scores were normalized and weighted in this study. LCIA results are relative expressions and do not predict impact on category endpoints, the exceeding of thresholds, safety margins or risks. Weighting is useful because it gives your results a single unit which is added up to create a single score for an environmental impact scenario. In other words, a value judgement is applied to the LCIA results so they can be more readily understood. The table below shows the normalization and weighting factors used to calculate the single score results.

**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 product studied. It details the results of the product per functional unit and concludes with recommendations. LCI and LCIA data can be seen in the LCA results spreadsheets [3] [4]. The results are presented per functional unit.

Yearly data for AFT was modeled in SimaPro. After results were calculated from SimaPro, the values were converted to mass per functional unit to get LCI and LCIA results. The sustainable minds scale for mPts conversion was used to calculate the mPts for the LCIA data.

### 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 [12].

Resource use indicators represent the amount of materials consumed to produce not only the insulation itself, but the raw materials, electricity, gasoline, etc. that go into the product's life cycle. Secondary materials used in the production of insulation include used newspaper fibers and waste paper.

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 was reported for each module. The biogenic content emissions and removals were due to cardboard and paper bags. Cardboard can be a product ingredient and paper bags are used for raw material packaging for some companies. These are both bio-based materials. Cardboard was not double counted, it is only considered as primary material.

Tables 5.1a shows the AFT product specific resource use, output and waste flows, and carbon emissions and removals for all loose-fill cellulose insulation per functional unit.

**Table 5.1a** Resource use, output & waste flows, carbon emissions & removals for AFT manufacturers loose-fill cellulose insulation per functional unit [3]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	Total
<i>Resource use indicators</i>																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	6.67E-02	6.02E-03	1.01E-04	0	0	0	0	0	0	0	0	1.82E-03	0	1.00E-03	<b>7.64E-02</b>
Renewable primary resources with energy content used as material	MJ, LHV	1.32E-01	0	2.16E-04	0	0	0	0	0	0	0	0	0	0	0	<b>1.32E-01</b>
Total use of renewable primary resources with energy content	MJ, LHV	1.99E-01	6.02E-03	3.17E-04	0	0	0	0	0	0	0	0	1.82E-01	0	1.00E-03	<b>2.09E-01</b>
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	4.76E00	9.72E-01	2.53E-02	0	0	0	0	0	0	0	0	2.95E-01	0	1.33E-01	<b>6.20E+00</b>
Non-renewable primary resources with energy content used as material	MJ, LHV	3.07E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>3.07E-03</b>
Total use of non-renewable primary resources with energy content	MJ, LHV	4.77E00	9.72E-01	2.55E-02	0	0	0	0	0	0	0	0	2.95E-01	0	1.44E-01	<b>6.20E+00</b>
Secondary materials	kg	5.82E-01	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>5.82E-01</b>
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>
Use of net fresh water resources	m3	7.62E-01	6.65E-02	1.11E-03	0	0	0	0	0	0	0	0	2.02E-02	0	1.09E-02	<b>8.61E-01</b>
<i>Output flows and waste category indicators</i>																
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>
Non-hazardous waste disposed	kg	7.41E-01	0	6.70E-02	0	0	0	0	0	0	0	0	0	0	6.70E-01	<b>7.37E-01</b>
High-level radioactive waste, conditioned, to final repository	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>
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	<b>0</b>
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>
<i>Carbon emissions and removals</i>																
Biogenic Carbon Removal from Product	kg CO <sub>2</sub>	1.42E-06	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>1.42E-06</b>
Biogenic Carbon Emission from Product	kg CO <sub>2</sub>	7.59E-03	0	0	0	0	0	0	0	0	0	0	0	0	1.47E-04	<b>8.10E-03</b>
Biogenic Carbon Removal from Packaging	kg CO <sub>2</sub>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>
Biogenic Carbon Emission from Packaging	kg CO <sub>2</sub>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO <sub>2</sub>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>0</b>

Calcination Carbon Emissions	kg CO <sub>2</sub>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbonation Carbon Removals	kg CO <sub>2</sub>	0	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 <sub>2</sub>	0	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 AFT's average loose-fill cellulose insulation product. 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, expressed in a common unit of kg CO<sub>2</sub> equivalents".

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. The impact categories required by the PCR are global warming potential, ozone depletion potential, acidification potential, eutrophication potential, smog formation potential, and fossil fuel depletion. Other categories are being developed and defined and LCA should continue making advances in their development; however, the TR users shall not use additional measures for comparative purposes. Impact categories which were not required by the PCR are included in additional environmental information section 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. Following table 5.2 displays the description of each impact category.

**Table 5.2** Impact category descriptions

Impact category	Description
Acidification	Indicator of potential acidification of soils and water due to the release of gases such as nitrogen oxides and Sulphur oxides.
Ecotoxicity	Impact on water and land organisms of toxic substances emitted to the environment.
Eutrophication	Indicator of the enrichment of the aquatic ecosystem with nutritional elements, due to the emission of nitrogen or phosphor containing compounds.

Global warming	Indicator of potential global warming due to emissions of greenhouse gases to air.
Ozone depletion	Indicator of emissions to air that cause the destruction of the stratospheric ozone layer.
Carcinogenics	Carcinogenic substances to have impact on humans.
Non carcinogenics	Non-carcinogenic substances to have an impact on humans.
Respiratory effects	Substances to have an impact on human respiratory system.
Smog	Indicator of emissions of gases that affect the creation of photochemical ozone in the lower atmosphere catalyzed by sunlight.
Fossil fuel depletion	Indicator of the depletion of natural fossil fuel resources.

### 5.2.1. Conventional Loose-Fill Cellulose Insulation

Tables 5.2.1a shows the contributions of each stage of the life cycle for the weighted average of AFT loose-fill cellulose Insulation.

For the loose-fill cellulose insulation product, the raw material acquisition, transportation to manufacturing facility, and manufacturing stage (A1-A3) dominates the results for all impact categories. Following these two stages, the next highest impacts come from transportation of the final products to distribution facilities (A4). The impact of the raw material acquisition stage is mostly due to certain chemicals such as boric acid and ammonium sulfate. The impacts of these chemicals are due to their processing and transportation phases. This could be due to high mass content of those ingredients. The electricity required to operate the facility is the largest contributor to the manufacturing stage. The contributions to outbound transportation (A4) are caused by the use of trucks during transport. The trucks are 20 ton trucks. 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 and the insulation blower machine used to install the product, which is the smallest contributor of all the stages.

Certain chemicals such as boric acid and ammonium sulfate are the main contributors to the raw material acquisition stage. Raw material inbound transportation is a small contributor to the impacts for this stage.

**Table 5.2.1a** Loose-fill cellulose 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 <sub>2</sub> eq	3.01E-03	3.25E-04	1.76E-05	0	0	0	0	0	0	0	0	9.85E-05	0	6.59E-05	<b>3.52E-03</b>
Eutrophication	kg N eq	3.14E-04	4.63E-05	1.41E-06	0	0	0	0	0	0	0	0	1.40E-05	0	7.59E-06	<b>3.83E-04</b>
Global warming	kg CO <sub>2</sub> eq	3.89E-01	8.70E-02	1.78E-03	0	0	0	0	0	0	0	0	2.64E-02	0	8.30E-03	<b>5.12E-01</b>
Ozone depletion	kg CFC-11 eq	4.91E-08	2.10E-08	3.01E-10	0	0	0	0	0	0	0	0	6.37E-09	0	3.00E-09	<b>7.98E-08</b>
Smog	kg O <sub>3</sub> eq	2.66E-02	6.61E-03	4.95E-04	0	0	0	0	0	0	0	0	2.00E-03	0	1.58E-03	<b>3.73E-02</b>
Fossil fuel depletion	MJ, LHV	5.87E-01	1.77E-01	4.65E-03	0	0	0	0	0	0	0	0	5.36E-02	0	2.60E-02	<b>8.49E-01</b>

#### **Additional environmental information**

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	Total
Carcinogenics	CTUh	5.01E-09	6.36E-10	2.25E-11	0	0	0	0	0	0	0	0	1.93E-10	0	7.90E-11	<b>5.94E-09</b>
Non-carcinogenics	CTUh	1.09E-07	1.87E-08		0	0	0	0	0	0	0	0	5.67E-09	0	7.97E-10	

				2.30E-10												<b>1.34E-07</b>
Ecotoxicity	CTUe	5.10E-01	3.51E-01	4.01E-03	0	0	0	0	0	0	0	0	1.06E-01	0	1.12E-02	<b>9.83E-01</b>
Respiratory effects	kg PM2.5 eq	3.38E-04	5.90E-05	9.86E-07	0	0	0	0	0	0	0	0	1.79E-05	0	8.07E-06	<b>4.24E-04</b>

### Single score results

The SM millipoint score by life cycle phase for this product is presented below (Table 5.2.1b). They do not conflict with the trends in the results using the impact assessment results before normalization and weighting. The raw material acquisition and manufacturing stage (A1-A3) dominates the results for all impact categories. Following these two stages, the next highest impacts come from transportation. The impact of the raw material acquisition stage is mostly due to certain chemicals such as boric acid and ammonium sulfate. This could be due to high mass content of those ingredients.

**Table 5.2.1e** Averaged SM millipoint scores for loose-fill cellulose insulation by life cycle stage per functional unit [5]

Impact category	Unit	Raw material acquisition and manufacturing	Transportation	Installation and maintenance	Transportation	Disposal	Total
		A1-A3	A4	A5	C2	C4	
SM single figure score	mPts	<b>3.40E-05</b>	<b>8.22E-06</b>	<b>1.78E-07</b>	<b>2.49E-06</b>	<b>7.25E-07</b>	<b>4.56E-05</b>

## 5.3 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 raw material acquisition, transportation to manufacturing facility, and the manufacturing stages (A1-A3) dominate the impacts due mainly to the raw materials required to make the products. Chemicals such as boric acid and ammonium sulfate had slightly higher environmental impacts.

Transportation of the final products to distribution facilities (A4) is the second highest contributor for the impact categories. The impact associated with outbound transport is consistently higher than that for inbound transport due to the further transportation distances.

Installation accounts for a small fraction of overall life cycle impact. The only installation impacts are associated with packaging disposal and the gas and electricity used for an installation blower machine. 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. For all products, waste was dominated by the final disposal of the product.

## 5.4 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 ecoinvent. The ecoinvent database and NERC datasets were used.

### *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 ecoinvent 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 ecoinvent databases. Allocation and other methodological choices were made consistently throughout the model.
- Reproducibility: disclosure of raw data, dataset choices, results and modeling approaches in this report would allow for reproducibility. 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 January 2018 through December 2018 in order to ensure representativeness of current production activities. All secondary data were obtained from the ecoinvent databases and are typically representative of the years 2008 – 2014.
- Geographical: Primary data are representative of AFT's production in the US; where country-specific data were unavailable, proxy data were used.
- Technological: All primary and secondary data were modeled to be specific to the technologies under study. Technological representativeness is considered to be high.

## 5.5 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*

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). New energy datasets were chosen and new results were compared to the original results; the difference in results did not vary by more than 20 percent.

### *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 ecoinvent databases. System boundaries, allocation rules, and impact assessment methods have been applied consistently throughout the study.

## 5.6 Conclusions, limitations, and recommendations

The goal of this study was to conduct a cradle-to-grave LCA on conventional loose-fill cellulose insulation for AFT so as to develop a product specific SM Transparency Report. The creation of this Transparency Report 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. Raw material acquisition and manufacturing emissions and energy consumption drive environmental performance. The gate-to-grave stages account for minimal contribution to life cycle performance.

The results show that the largest area for reduction of each product's environmental impact is in the raw material acquisition and manufacturing phase. With further analysis, the greatest impacts in A1-A3 come from A1 (raw material acquisition). This is an important area for the AFT to focus its efforts and one which it can influence; it can significantly reduce its raw material acquisition impacts by changing the specific kinds of raw materials used in the product for alternative solutions that might have less of an impact. The chemicals used as raw materials in this product, such as boric acid and different kinds of sulfates, are the ones with the most impact in A1. Furthermore, AFT can potentially reduce their manufacturing impacts by decreasing electricity in the manufacturing facilities or using renewable energy. This can be done by turning off certain machines when they are not in use. Companies are also recommended to recycle their dust emissions back into their product to reduce manufacturing impacts.

Limitations to this study is that it is a product specific LCA done from an industry average; some of the values used, were applied to the industry average study done previously. In other words, the data used for this study was the data originally collected for an industry wide LCA. Due to this, some of the datasets are old and thus a limitation to the study.

The methodology and results lead to an overall picture of the product and since an industry wide EPD has been published, AFT can now compare their own results with the

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industry average results. AFT can better understand their own product relative to the average; they can see if they performed better or worse than the average and opportunities for change and improvement will be apparent. A product specific EPD provides a more competitive edge to those who are focusing on improving their own products.

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## ACRONYMS

<b>ISO</b>	International Standardization Organization
<b>LCA</b>	life cycle assessment
<b>LCI</b>	life cycle inventory
<b>LCIA</b>	life cycle impact analysis
<b>PCR</b>	Product Category Rule document
<b>TR</b>	Transparency Report™
<b>ts</b>	thinkstep
<b>ULE</b>	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:

<b>allocation</b>	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
<b>close loop &amp; open loop</b>	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.
<b>cradle to grave</b>	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
<b>cradle to gate</b>	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
<b>declared unit</b>	quantity of a product for use as a reference unit in an EPD based on one or more information modules
<b>functional unit</b>	quantified performance of a product system for use as a reference unit
<b>life cycle</b>	consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal
<b>life cycle assessment - LCA</b>	compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle
<b>life cycle impact assessment - LCIA</b>	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
<b>life cycle inventory - LCI</b>	phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle

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**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

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## 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 – AFT\_LCIA\_results
- LCA results – AFT\_LCI\_results
- Primary data\_AFT\_Mastersheet\_primarydata