LIFE CYCLE ASSESSMENT (LCA) OF CIMA LOOSEFILL CELLULOSE INSULATION PRODUCTS

Status: Final

Client: CIMA and CIMAC

Date: Published: November 2019
Updated: March 2021

Author(s): Sustainable Minds

Contents

1 INTRODUCTION

1.1 Opportunity

CIMA is a trade association made up of cellulose insulation producers and affiliated members dedicated to ensuring the highest quality cellulose insulation products and standards [1]. In fulfilling their commitment to sustainability, it is important for CIMA to conduct an industry wide 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 industry wide 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 CIMA'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, CIMA 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.

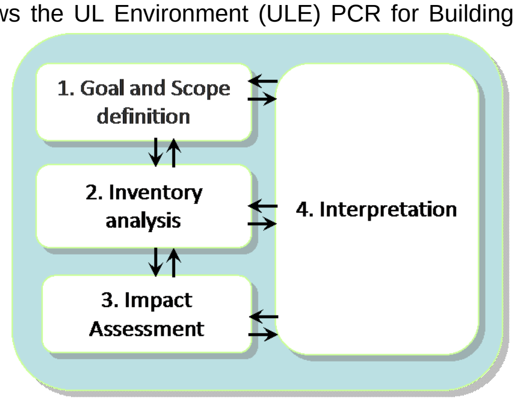
CIMA is interested in having a Life Cycle Assessment (LCA) conducted on conventional loose-fill cellulose insulation, so that they can have the data available to the public within a Sustainable Minds Transparency Report™. A Sustainable Minds Transparency Report™ is a Type III Environmental Declaration 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.

CIMA commissioned Sustainable Minds to develop an LCA for a typical loosefill cellulose insulation product manufactured by its members. CIMA wants its members to be able to compare this industry-wide TR to their own product-specific TRs so that they have guidance for future product improvements.

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 [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 CIMA members at the time it was collected, and best practices were conducted by Sustainable Minds and CIMA employees and members to transform this information into this LCA report. The data covers annual manufacturing data for 1/2018-12/2018 from thirteen of CIMA's members:

1. Advanced Fiber Technology (AFT)
2. Applegate Insulation
3. Can-Cell Industries (CCI)
4. Cell-Pak
5. Cleanfiber
6. Climatizer
7. Fiberlite
8. Igloo Cellulose
9. International Cellulose Corporation (ICC)
10. Mason City Recycling Center
11. Nu-Wool
12. Soprema
13. Thermo-Kool

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

The data from each manufacturer represents one manufacturing location except for Applegate. Data from Applegate is representative of eight manufacturing locations.

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

CIMA 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 CIMA:

- Dan Lea, Executive Director CIMA

Dan has been assisted by numerous CIMA members during the data collection, reporting, and interpretation phases.

From Sustainable Minds:

- Kelli Young, LCA Practitioner
- Kim Lewis, LCA Internal Reviewer

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 the CIMA 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 CIMA members 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

Founded in 1992, CIMA is the trade association for the cellulose segment of the thermal/acoustical insulation industry. Cellulose insulation from members of CIMAC and CIMA is available in every province in Canada and state in North America. Canadian participants in the EPD represent 67% of CIMAC members and 57% of the total Canadian cellulose insulation industry. In the US participating CIMA members represent 69% of the association's membership and 56% of the total US cellulose insulation industry. As an organization of manufacturers that produce cellulose insulation, CIMA 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 CIMA products, go to https://www.cellulose.org/.

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.

The products studied in this report are listed in Table 2.2a with the company names and the manufacturing locations. Declaration names with products represented and type of declaration for the product are listed in Table 2.2b. The average product represents cellulose insulation from 13 manufacturers; due to the nature of cellulose insulation the material ingredients used, manufacturing and installation processes, there is little variation between the primary data collected from each manufacturer.

Table 2.2a Manufacturing locations

Company	Product name	Manufacturing location(s)
AFT	AFT Loose Fill / AFT Wall Spray	Bucyrus, OH
Applegate	Applegate Cellulose Insulation	Casa Grande, AZ; Penrose, CO; Webberville, MI; Hickory, KY; Eastanollee, GA; Monroe, LA; Bloomer, WI; Chambersburg, PA
Can-Cell (CCI)	Weathershield and WallBAR Cellulose Fibre Insulation, HiBAR Spray-Applied Fire Resistant Material	Edmonton, Alberta, Canada
Cell-Pak	Proshredz, Maxshredz, Smartshredz, Supremeplus, Chickshredz	Decatur, AL
Cleanfiber	Cleanfiber	Buffalo, NY
Climatizer	Loose-fill Cellulose Insulation	Toronto, Ontario, Canada
Fiberlite	Attic Plus Pro	Joplin, MO
Igloo Cellulose	AFT Loose Fill	Dorval, QC, Canada
International Cellulose Corporation (ICC)	Celbar Loose Fill	Houston, TX
Mason City Recycling Center	Comfortzone Cellulose Insulation	Mason City, IA
Nu-Wool	Nu Wool Premium Cellulose, Energy Care Cellulose, Insulmax	Jenison, MI
Soprema	Sopra-Cellulose	Sainte Julie, QC, Canada
Thermo-Kool	Mono-Therm, Northern Fiber, Arctic Fiber loose fill cellulose insulation	Wasilla, AK

Table 2.2b Industry-wide 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 / AFT Wall Spray	Thirteen specific products as an average from several of the manufacturer's plants
	Applegate	Applegate Cellulose Insulation	
	Can-Cell (CCI)	Weathershield and WallBAR Cellulose Fibre Insulation, HiBAR Spray-Applied Fire Resistant Material	
	Cell-Pak	Proshredz, Maxshredz, Smartshredz, Supremeplus, Chickshredz	
	Cleanfiber	Cleanfiber	
	Climatizer	Loose-fill Cellulose Insulation	
	Fiberlite	Attic Plus Pro	
	Igloo Cellulose	AFT Loose Fill	
	International Cellulose Corporation (ICC)	Celbar Loose Fill	
	Mason City Recycling Center	Comfortzone Cellulose Insulation	

	Nu-Wool	Nu Wool Premium Cellulose, Energy Care Cellulose, Insulmax	
	Soprema	Sopra-Cellulose	
	Thermo-Kool	Mono-Therm, Northern Fiber, Arctic Fiber loose fill cellulose insulation	

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^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 [2]. Therefore, the insulation does not need to be replaced, and 1 m^2 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 $m^2 \cdot K/W$, 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 RSI=1 (m)	Reference flow total (kg)
AFT	AFT Loose Fill / AFT Wall Spray	[redacted]	.0609	.0381	.960
Applegate	Applegate Cellulose Insulation	[redacted]	.0050	.0412	.835
Can-Cell (CCI)	Weathershield and WallBAR Cellulose Fibre Insulation, HiBAR Spray-Applied Fire Resistant Material	[redacted]	.179	.041	1.18
Cell-Pak	Proshredz, Maxshredz, Smartshredz, Supremeplus, Chickshredz	[redacted]	.0001	.0390	.993
Cleanfiber	Cleanfiber	[redacted]	.0053	.0396	.933
Climatizer	Loose-fill Cellulose Insulation	[redacted]	.0068	.041	1.08
Fiberlite	Attic Plus Pro	[redacted]	.0057	.0380	0.973
Igloo Cellulose	AFT Loose Fill	[redacted]	.0051	.0433	1.02
International Cellulose Corporation (ICC)	Celbar Loose Fill	[redacted]	.0066	.0406	.938
Mason City Recycling Center	Comfortzone Cellulose Insulation	[redacted]	.0020	.0389	.961
Nu-Wool	Nu Wool Premium Cellulose, Energy Care Cellulose, Insulmax	[redacted]	.0021	.0381	1.005
Soprema	Sopra-Cellulose	[redacted]	.0007	.0398	.973
Thermo-Kool	Mono-Therm, Northern Fiber, Arctic Fiber loose fill cellulose insulation	[redacted]	.0070	.0383	0.936

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 CIMA 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.

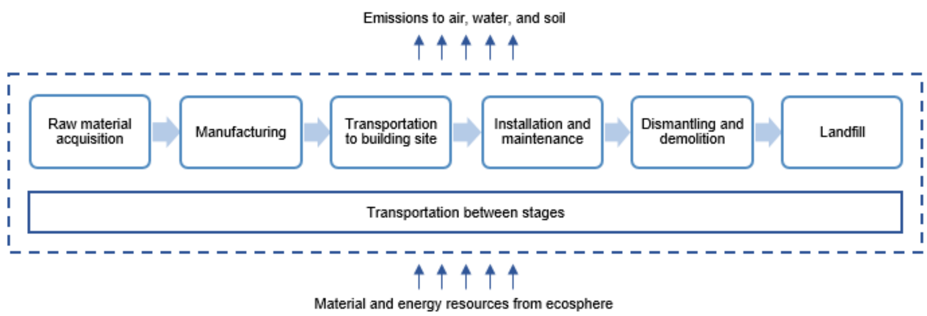


Figure 2.4a Applied system boundaries for the modeled insulation product

Table 2.4a System boundaries

Included	Excluded
• Raw material acquisition and processing • Processing of materials • 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. A1-A3: Raw materials acquisition, transportation, and manufacturing

Raw materials acquisition and transportation (A1-A2)

The RM acquisition and transportation 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.

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, 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

2.4.3. 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 CIMA members 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 CIMA manufacturers.

- **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; these are based off of the material ingredients provided by each of the manufacturers. Detailed database documentation for ecoinvent can be accessed at: https://www.ecoinvent.org/database/database.html.

All primary data were provided by CIMA manufacturers. 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 CIMA 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 CIMA manufacturers. Results were then scaled to reflect the functional unit.

Each company provided data from just one manufacturing facility except Applegate. Applegate provided data for the insulation product from several different manufacturing facilities. The data from the different Applegate manufacturing facilities was summed up to provide inputs for all modules except the transportation modules. Transportation values were calculated by multiplying the kilograms transported by the kilometers traveled for each manufacturing facility. These values were then summed up for a final result.

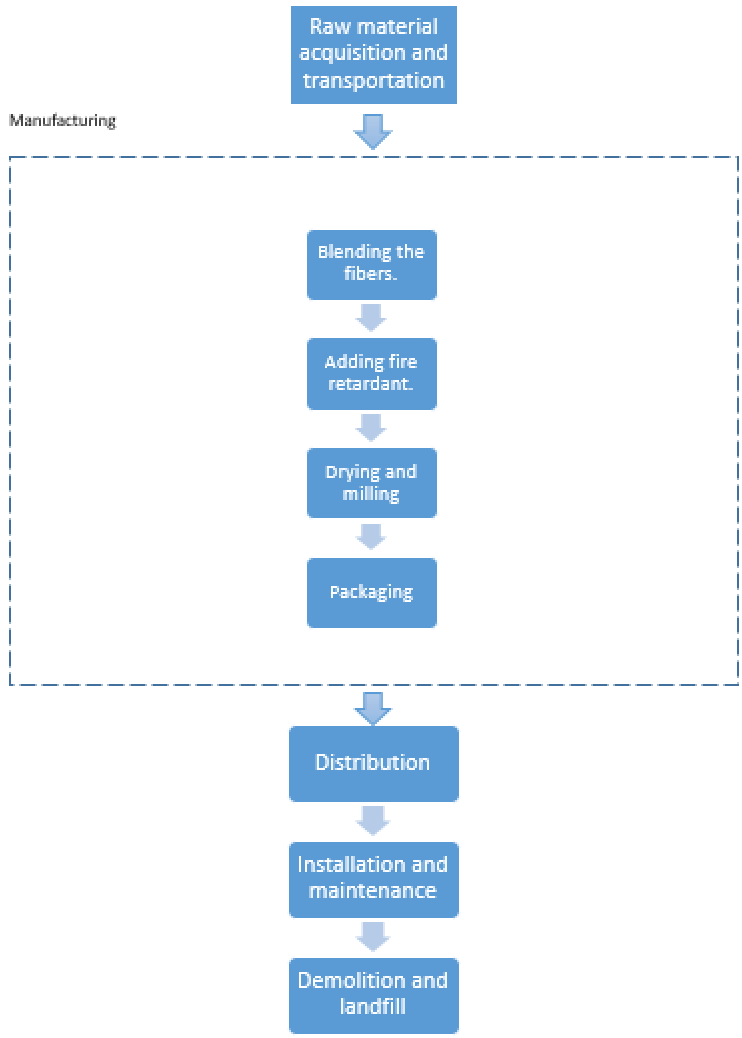


Figure 3.2a Life cycle flow chart of insulation product production

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 CIMA member manufacturing facilities.

Mixed papers, boric acid, sodium borate, mineral oil and other raw materials are transported to manufacturing facilities. 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 processessing 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 CIMA's facilities via both truck, rail, and boat. Facility locations for each company are listed in Table 2.2a. All CIMA manufacturers in this study have one manufacturing facility that the raw materials are shipped to except Applegate, which has eight facilities Transport data were collected for each flow and are shown in Tables 3.2a-m. Table 3.2n shows the average material composition percentages for all manufacturers; 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 each of the manufacturers. The average material composition in table 3.2n is the averaged mass percentage for each of the material ingredients from each of thirteen manufacturers. For example, mass percentage of boric acid was calculated for each manufacturer which provides 13 mass percentage results; those 13 mass percentage results are averaged to get the average mass percentage of boric acid.

Table 3.2a AFT raw material inputs

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

Table 3.2b Applegate raw material inputs

Flow	Mass percentage	Transportation mode	Distance (km)
[redacted]	[redacted]	Truck and trailer	388.67
[redacted]	[redacted]	Truck	645.56
[redacted]	[redacted]	Truck	1,224.03
[redacted]	[redacted]	Tanker truck	79.95
[redacted]	[redacted]	Tanker truck	760.87
[redacted]	[redacted]	Truck and trailer	804.67
[redacted]	[redacted]	Truck	937.33
[redacted]	[redacted]	Truck and trailer	1,476.28

[redacted]	[redacted]		
[redacted]	[redacted]	Truck and trailer	388.67
[redacted]	[redacted]	Truck and trailer	5,087.86

Table 3.2c Can-Cell (CCI) raw material inputs

Flow	Mass percentage	Transportation mode	Distance (km)
[redacted]	[redacted]	Truck and bin	1
[redacted]	[redacted]	Truck and trailer	1
[redacted]	[redacted]	Train	2800
[redacted]	[redacted]	Trailer bin and hopper	40
[redacted]	[redacted]	Trailer	510
[redacted]	[redacted]		
[redacted]	[redacted]	Truck and trailer	3300
[redacted]	[redacted]	Truck and trailer	3300
[redacted]	[redacted]	Truck and trailer	20
[redacted]	[redacted]	Truck and trailer	20

Table 3.2d Cell-Pak raw material inputs

Flow	Mass percentage	Transportation mode	Distance (km)
[redacted]	[redacted]	Truck	1248.85
[redacted]	[redacted]	Truck	1118.49
[redacted]	[redacted]	Truck	540.74
[redacted]	[redacted]	Truck	450.62
[redacted]	[redacted]	Tanker	513.38
[redacted]	[redacted]	Truck	482.8
[redacted]	[redacted]	Truck	1073.43
[redacted]	[redacted]		
[redacted]	[redacted]	Truck	482.8
[redacted]	[redacted]	Truck	540.74
[redacted]	[redacted]	Truck	450.62

Table 3.2e Cleanfiber raw material inputs

Flow	Mass percentage	Transportation mode	Distance (km)
[redacted]	[redacted]	Truck and trailer	201.17
[redacted]	[redacted]	Truck and trailer	40.23
[redacted]	[redacted]	Truck and trailer	1287.47
[redacted]	[redacted]	Truck	80.47
[redacted]	[redacted]	N/A	N/A
[redacted]	[redacted]	18 wheel trailer	1937.65
[redacted]	[redacted]		
[redacted]	[redacted]	Truck and trailer	201.17
[redacted]	[redacted]	18 wheel trailer	1937.65

Table 3.2f Climatizer raw material inputs

Flow	Mass percentage	Transportation mode	Distance (km)
[redacted]	[redacted]	Truck and trailer	18
[redacted]	[redacted]	Truck and trailer	18
[redacted]	[redacted]	Truck and trailer	18
[redacted]	[redacted]	Truck and trailer	45
[redacted]	[redacted]	Truck and trailer	93
[redacted]	[redacted]	Tanker	10
[redacted]	[redacted]		

[redacted]	[redacted]	Truck and trailer	18

Table 3.2g Fiberlite raw material inputs

Flow	Mass percentage	Transportation mode	Distance (km)
[redacted]	[redacted]	Truck and trailer	407.16
[redacted]	[redacted]	Truck and trailer	1892.58
[redacted]	[redacted]	Truck and trailer	943.07
[redacted]	[redacted]	Truck and trailer	943.07
[redacted]	[redacted]	Truck and trailer	17.7
[redacted]	[redacted]	Truck and trailer	944.68
[redacted]	[redacted]		
[redacted]	[redacted]	Truck and trailer	407.16
[redacted]	[redacted]	Truck and trailer	407.16

Table 3.2i Igloo Cellulose raw material inputs

Flow	Mass percentage	Transportation mode	Distance (km)
[redacted]	[redacted]	Rail and truck	10705
[redacted]	[redacted]	Ocean and truck	7725
[redacted]	[redacted]	Ocean and truck	35
[redacted]	[redacted]	Truck and trailer	387.5
[redacted]	[redacted]	N/A	N/A
[redacted]	[redacted]	Truck and trailer	55
[redacted]	[redacted]		
[redacted]	[redacted]	Truck and trailer	387.5

Table 3.2h International Cellulose Corporation (ICC) raw material inputs

Flow	Mass percentage	Transportation mode	Distance (km)
[redacted]	[redacted]	Truck and trailer	40.23
[redacted]	[redacted]	Truck and trailer	24.14
[redacted]	[redacted]	Truck and trailer	24.14
[redacted]	[redacted]	Truck and trailer	0.32
[redacted]	[redacted]	Box truck	67.59
[redacted]	[redacted]		
[redacted]	[redacted]	Truck and trailer	40.23
[redacted]	[redacted]	Box truck	67.59

Table 3.2k Mason City Recycling Center raw material inputs

Flow	Mass percentage	Transportation mode	Distance (km)
[redacted]	[redacted]	Rail and truck	2735.88
[redacted]	[redacted]	Truck	1915.11
[redacted]	[redacted]	Truck	3.22
[redacted]	[redacted]	Semi-truck	241.40
[redacted]	[redacted]	Semi-truck	2596.99
[redacted]	[redacted]		
[redacted]	[redacted]	Semi-truck	241.40

Table 3.2j Nu-Wool raw material inputs

Flow	Mass percentage	Transportation mode	Distance (km)
[redacted]	[redacted]	Boat and truck	1153.9
[redacted]	[redacted]	Train and truck	3049.70
[redacted]	[redacted]	Truck and trailer	273.59

[redacted]	[redacted]	Train and truck	32.19
[redacted]	[redacted]	Bulk tanker truck	24.1401
[redacted]	[redacted]		
[redacted]	[redacted]	Truck and trailer	273.59

Table 3.2l Soprema raw material inputs

Flow	**Mass percentage**	**Transportation mode**	**Distance (km)**
[redacted]	[redacted]	Truck and trailer	2179
[redacted]	[redacted]	Truck with cistern	60
[redacted]	[redacted]	Truck and trailer	50
[redacted]	[redacted]	Truck and trailer	650
[redacted]	[redacted]	Truck and trailer	40
[redacted]	[redacted]	N/A	20

Table 3.2m Thermo-Kool raw material inputs

Flow	**Mass percentage**	**Transportation mode**	**Distance (km)**
[redacted]	[redacted]	Truck and trailer; barge	4181.07
[redacted]	[redacted]	Truck and barge	2336.76
[redacted]	[redacted]	Truck and trailer	72.42
[redacted]	[redacted]	Truck and trailer	72.42
[redacted]	[redacted]	Semi-truck and trailer; barge	2655.41
[redacted]	[redacted]	14” Box van	9.66
[redacted]	[redacted]		
[redacted]	[redacted]	Truck and trailer	144.84
[redacted]	[redacted]	Semi-truck and trailer; barge	2655.41

Table 3.2n Average Mass Composition for Raw Material Inputs

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]
[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%

There is a greater than 20% variation for the raw material inputs because the facilities use a varying amount of each ingredient to make their product. The raw material input variation increases the variation in the life cycle assessment results.

3.2.2. Manufacturing (A3)

After the raw materials are transported to CIMA's facilities, the newspaper or other fiber raw material inputs are shredded. 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 Tables 3.2.2a-m. Emissions associated with the production of electricity and the combustion of natural gas are accounted for in the ecoinvent background processes. Dust emissions are accounted for most facilities. Several manufacturers have no dust emissions because they recycle it back into the product.

Table 3.2.2a AFT annual manufacturing inputs and outputs

	Flow	**Amount**	**Unit**
Inputs	Electricity (NERC)	[redacted]	kWh
	Oil/grease	[redacted]	kg
Outputs	Packaged product	[redacted]	kg
	Empty packaging	[redacted]	kg
	Wastepaper wires (raw material packaging)	[redacted]	kg
	Unusable wastepaper	[redacted]	kg
	Dust	[redacted]	kg

Table 3.2.2b Applegate annual manufacturing inputs and outputs

	Flow	**Amount**	**Unit**
Inputs	Electricity (NERC)	[redacted]	kWh
	Hydraulic oil	[redacted]	kg
Outputs	Packaged product	[redacted]	kg
	Bailing wire (raw material packaging)	[redacted]	kg
	Packaging	[redacted]	kg
	Unusable fiber	[redacted]	kg
	Other	[redacted]	kg
	Dust	[redacted]	kg

Table 3.2.2c Can-Cell (CCI) annual manufacturing inputs and outputs

	Flow	**Amount**	**Unit**
Inputs	Electricity (CA-AB)	[redacted]	kWh
Outputs	Packaged product	[redacted]	kg

Table 3.2.2d Cell-Pak annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity (NERC)	[redacted]	kWh
	Hydraulic oil	[redacted]	kg
Outputs	Packaged product	[redacted]	kg
	Empty packaging	[redacted]	kg
	Wastepaper wires (raw material packaging)	[redacted]	kg
	Unusable wastepaper	[redacted]	kg
	Dust	[redacted]	kg

Table 3.2.2e Cleanfiber annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity (NERC)	[redacted]	kWh
	Natural gas	[redacted]	CCF
Outputs	Packaged product	[redacted]	kg
	Cellulose fines	[redacted]	kg
	Wastepaper wires (raw material packaging)	[redacted]	kg
	Unusable wastepaper	[redacted]	kg
	Shrink wrap (raw material packaging)	[redacted]	kg
	Dust	[redacted]	kg

Table 3.2.2f Climatizer annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity (CA-ON)	[redacted]	kWh
	Grease	[redacted]	kg
	Propane	[redacted]	kg
	Diesel	[redacted]	kg
Outputs	Packaged product	[redacted]	kg
	Wire wrapping (raw material packaging)	[redacted]	kg
	Dust	[redacted]	kg

Table 3.2.2g Fiberlite annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity (NERC)	[redacted]	kWh
Outputs	Packaged product	[redacted]	kg
	Cellulose fines	[redacted]	kg
	Wire wrapping (raw material packaging)	[redacted]	kg
	Dust	[redacted]	kg

Table 3.2.2h Igloo Cellulose annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity (NERC)	[redacted]	kWh
	Oil/ grease	[redacted]	kg
Outputs	Packaged product	[redacted]	kg
	Wire wrapping (raw material packaging)	[redacted]	kg
	Dust of paper	[redacted]	kg
	Plastic bags	[redacted]	kg

	Dust	[redacted]	kg

Table 3.2.2i International Cellulose Corporation (ICC) annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity (NERC)	[redacted]	kWh
Outputs	Packaged product	[redacted]	kg
	Wire wrapping (raw material packaging)	[redacted]	kg
	Cardboard box (raw material packaging)	[redacted]	kg

Table 3.2.2j Mason City Recycling Center annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity (NERC)	[redacted]	kWh
	Oil/ grease	[redacted]	kg
Outputs	Packaged product	[redacted]	kg
	Unusable wastepaper and plastic	[redacted]	kg
	Bailed wire (raw material packaging)	[redacted]	kg

Table 3.2.2k Nu-Wool annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity (NERC)	[redacted]	kWh
	Natural gas	[redacted]	CCF
	Oil/ grease	[redacted]	kg
Outputs	Packaged product	[redacted]	kg
	Wire wrapping (raw material packaging)	[redacted]	kg

Table 3.2.2l Soprema annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity (CA-QC)	[redacted]	kWh
Outputs	Packaged product	[redacted]	kg
	Non-toxic waste	[redacted]	kg

Table 3.2.2m Thermo-Kool annual manufacturing inputs and outputs

	Flow	Amount	Unit
Inputs	Electricity (NERC)	[redacted]	kWh
	Grease	[redacted]	Kg
	Lube	[redacted]	Kg
	Chain lube	[redacted]	Kg
	Hydraulic oil	[redacted]	Kg
Outputs	Packaged product	[redacted]	Kg
	Wire ties	[redacted]	Kg
	Plastic bag (raw material packaging)	[redacted]	Kg
	Plastic wrap (raw material packaging)	[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 and Canada. All CIMA manufacturers in this study have one manufacturing facility that the products are shipped from except Applegate, which has eight facilities. Applegate distribution data from eight facilities as summed together to get a total transportation value. Table 3.2.3 details insulation distribution. The distribution data was provided directly from the manufacturers; there is vaiartion in the data provided; however, these distances to the distributors were confirmed by the manufactuerers.

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
Applegate	405.55	km
Can-Cell (CCI)	621.2	km
Cell-Pak	965.6	km
Cleanfiber	402.34	km
Climatizer	125.53	km
Fiberlite	418.43	km
Igloo Cellulose	749.95	km
International Cellulose Corporation (ICC)	152.08	km
Mason City Recycling Center	563.27	km
Nu-Wool	804.67	km
Soprema	292.9	km
Thermo-Kool	177.03	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 manufacturer [5]. Based on data given by manufacturers, the amount of electricity and gasoline used in installation by blowers annually was modeled and is shown in Table 3.2.4a.

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 for each company.

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. 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 all of the manufacturers. This distance was assumed because it was the farthest distance provided to a landifll and therefore the most conservative assumption. 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. 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.
- Any missing data was confirmed to the manufacturers and was treated using assumptions, averages and datasets.

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 CIMA members. 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 CIMA member facilities in the US and Canada.

Geographical coverage. CIMA manufacturers have several facilities across the United States and Canada. As such, the geographical coverage for this study is based on North American system boundaries for all processes and products. Whenever US or Canadian 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 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 sets were used for all companies. Can-Cell (CCI), Climatizer, Igloo, and Soprema all have facilities in Canada. Canadian data sets were used for these companies. 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- RFC	NERC	2014	US RFC
Electricity	Electricity- WECC	NERC	2014	US WECC
Electricity	Electricity- SERC	NERC	2014	US SERC
Electricity	Electricity- NPCC	NERC	2014	US NPCC
Electricity	Electricity- TRE	NERC	2014	US TRE
Electricity	Electricity- MRO	NERC	2014	US MRO
Electricity	Electricity- ASCC	NERC	2014	US ASCC
Electricity	Electricity- CA-AB	StatCan	2014	CA AB
Electricity	Electricity- CA-ON	StatCan	2014	CA ON
Electricity	Electricity- CA-QC	StatCan	2014	CA QC
Technical heat	Heat, natural gas	EI v3	2014	Global
Gasoline	Gasoline, combusted in equipment	US LCI	2008	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 the most relevant 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	EI v3	2014	Global
Product	Ammonium sulfate	EI v3	2014	Global
Product	Chemical, organic	EI v3	2014	Global
Product	Chemical, inorganic	EI v3	2014	Global
Product	Maize starch	EI v3	2014	Global
Product	White mineral oil	EI 2.2	2008	North America
Product	Gypsum, mineral	EI v3	2014	Global
Product and packaging	Corrugated board box	EI v3	2014	Global
Product	Water, ultrapure	EI v3	2014	Global
Product	Sodium borates	EI v3	2014	Global
Product	Zinc monosulfate	EI v3	2014	Global
Product	Ammonium sulfate	EI v3	2014	Global
Product	Borax, anhydrous powder	EI v3	2014	Global
Product	Polycarbonate	EI v3	2014	Global
Packaging	Packaging film, low density polyethylene	EI v3	2014	Global
Packaging	Kraft paper, unbleached	EI v3	2014	Global
Packaging	Steel low-alloyed	EI v3	2014	Global

3.4.3. Transportation

Average transportation distances and modes of transport are included for the transport of the raw materials to production facilities. Typical vehicles used include trailers, rail cars, and boats.

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, lorry, 16-32 metric ton	EI v3	2014	Global
Tanker truck, 6,500 gallon	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Truck and trailer	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Truck	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Tanker truck	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Tanker, 6,000 gallon	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Truck and trailer, 16 ton	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Truck and trailer, 22 ton	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Truck, 10 ton	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
18 wheel trailer	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Truck and trailer, 53 ft	Transport, lorry, 16-32 metric ton	EI v3	2014	Global

Semi-truck	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Truck with cistern	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Box truck, 26 ft	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Truck and trailer 45 ft	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Boat	Transport, freight, sea	EI v3	2014	Global
Barge	Transport, freight, sea	EI v3	2014	Global
Rail	Transport, freight, train	EI v3	2014	Global

3.4.4. Disposal

Disposal processes were obtained from the ecoinvent databases. These processes were chosen to correspond to the materials being disposed, which are 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	EI v3	2014	Global
Other	Inert waste, for final disposal	EI v3	2014	Global
Shrink/plastic wrap	Inert waste, for final disposal	EI v3	2014	Global
Unusable fiber	Inert waste, for final disposal	EI v3	2014	Global
Cellulose fines	Inert waste, for final disposal	EI v3	2014	Global
Cardboard box	Inert waste, for final disposal	EI v3	2014	Global
Dust of paper	Inert waste, for final disposal	EI v3	2014	Global
Non toxic waste	Inert waste, for final disposal	EI v3	2014	Global
Empty packaging	Inert waste, for final disposal	EI v3	2014	Global
Plastic bag	Inert waste, for final disposal	EI v3	2014	Global
PE film	Inert waste, for final disposal	EI v3	2014	Global
Product	Inert waste, for final disposal	EI v3	2014	Global

3.4.5. Emissions to air, water, and soil

All gate-to-gate emissions reported by CIMA manufacturers for the manufacturing stage are taken into account in the study. Emissions measured and reported by CIMA are detailed under primary data collection. Dust is emitted by nearly all facilities except a few who recycle the dust back into the production process. The manufacturers that do emit dust gave the amount of dust emitted annually. 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 natural gas combustion 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 $R_{SI} = 1\ m^2 \cdot K/W$ [2], it should be noted that a product with this R-value is not sold by CIMA. The declared product is delivered to the site of installation with the R-value chosen by the customer.

Data were collected from each participating CIMA manufacturer. Each CIMA manufacturer represents one facility except for Applegate. The data from Applegate facilities is added together to represent their product.

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

There are limitations to an industry average EPD. First, is that each of the manufacturers' products are being represented by an average even though some fall above and some fall below. With an industry average LCA you cannot compare the results of each individual manufacturer to each other or to the average. An industry average EPD is not meant to be a comparative tool.

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.

- 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. 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 CIMA manufacturers each provided data for one product and one facility except for Applegate. Applegate provided data for one product in eight facilities. The data for each facility was summed up to calculate data representative of all the Applegate facilities. Allocation was not necessary in these calculations.

Mass allocation was used for Cleanfiber to calculate waste in the manufacturing stage. Wastepaper wires and unusable wastepaper was calculated by calculating the ratios of wastepaper wires and unusable wastepaper to product output for each company. The most conservative calculations were used for Cleanfiber. Dust emissions were also calculated this way for Cleanfiber.

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.

3.8 Software and database

The LCA model was created using SimaPro Analyst 8.5.2.0 for life cycle engineering. The ecoinvent 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 products.

3.9 Critical review

This is a supporting LCA report for a CIMA industry-wide loose-fill cellulose insulation Transparency Report and will be evaluated for conformance to the PCR 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 [8] (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 [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_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 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.

[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.

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 average product studied. It details the results as an average of products per functional unit of each product 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 each company's product was modeled in SimaPro. After results were calculated for each company from SimaPro, the values were converted to mass per functional unit. A weighted average was then calculated for each LCI and LCIA result. The weighted average was calculated by using the production volume of the product from each company. No renewable energy was used in production, and no energy was recovered.

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, natural gas, 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 CIMA industry average 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 CIMA 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**
Resource use indicators																
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	5.36E-01	8.92E-03	5.75E-05	0	0	0	0	0	0	0	0	2.60E-03	0	1.43E-03	**5.49E-01**
Renewable primary resources with energy content used as material	MJ, LHV	7.98E-01	0	8.53E-05	0	0	0	0	0	0	0	0	0	0	0	**7.98E-01**
Total use of renewable primary resources with energy content	MJ, LHV	1.33E00	8.92E-03	1.43E-04	0	0	0	0	0	0	0	0	2.60E-03	0	1.43E-03	**1.35E00**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	2.19E01	1.44E00	2.97E-02	0	0	0	0	0	0	0	0	4.20E-01	0	2.05E-01	**2.40E01**
Non-renewable primary resources with energy content used as material	MJ, LHV	1.88E-03	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.88E-03**
Total use of non-renewable primary resources with energy content	MJ, LHV	2.19E01	1.44E00	2.98E-02	0	0	0	0	0	0	0	0	4.20E-01	0	2.05E-01	**2.40E01**
Secondary materials	kg	1.65E00	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.65E00**
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	6.36E00	9.86E-02	6.60E-04	0	0	0	0	0	0	0	0	2.88E-02	0	1.55E-02	**6.51E00**
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	2.51E-02	0	0	0	0	0	0	0	0	0	0	9.55E-01	**9.80E-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	5.67E-04	0	0	0	0	0	0	0	0	0	0	0	0	0	**5.67E-04**
Biogenic Carbon Emission from Product	kg CO_2	3.11E-02	4.53E-04	1.56E-06	0	0	0	0	0	0	0	0	1.32E-04	0	5.85E-04	**3.17E-02**
Biogenic Carbon Removal from Packaging	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Biogenic Carbon Emission from Packaging	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
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%

There is a variation greater than 20% because of the differences in all the modules for each product of the participating companies. The companies have different manufacturing procedures for their products, different raw materials and mass composition for the raw materials, different transportation distances and methods etc. The variation essentially depicts the differences between the companies. A greater variation effects the results by making them more variable.

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 CIMA'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 CO2 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 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. Conventional Loose-Fill Cellulose Insulation

Tables 5.2.1a shows the contributions of each stage of the life cycle for the weighted average of the thirteen CIMA manufacturers for 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 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, ship, and rail transport. The trucks/boats/rail are not weight limited or volume limited. 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_2 eq	3.26E-03	3.36E-04	1.89E-05	0	0	0	0	0	0	0	0	9.80E-05	0	6.72E-05	**3.78E-03**
Eutrophication	kg N eq	4.22E-04	4.79E-05	1.21E-06	0	0	0	0	0	0	0	0	1.40E-05	0	7.75E-06	**4.93E-04**
Global warming	kg CO_2 eq	4.87E-01	8.99E-02	1.70E-03	0	0	0	0	0	0	0	0	2.62E-02	0	8.47E-03	**6.13E-01**
Ozone depletion	kg CFC-11 eq	7.20E-08	2.17E-08	7.97E-11	0	0	0	0	0	0	0	0	6.34E-09	0	3.06E-09	**1.03E-07**
Smog	kg O_3 eq	3.37E-02	6.83E-03	5.67E-04	0	0	0	0	0	0	0	0	1.99E-03	0	1.61E-03	**4.47E-02**
Fossil fuel depletion	MJ, LHV	7.99E-01	1.83E-01	3.88E-03	0	0	0	0	0	0	0	0	5.33E-02	0	2.65E-02	**1.07E00**

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

Additional environmental information

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	Total
Carcinogenics	CTUh	6.46E-09	6.56E-10	2.49E-11	0	0	0	0	0	0	0	0	1.91E-10	0	8.06E-11	**7.41E-09**
Non-carcinogenics	CTUh	8.25E-08	1.93E-08	2.56E-10	0	0	0	0	0	0	0	0	5.64E-09	0	8.13E-10	**1.09E-07**
Ecotoxicity	CTUe	6.71E-01	3.63E-01	4.80E-03	0	0	0	0	0	0	0	0	1.06E-01	0	1.15E-02	**1.16E00**
Respiratory effects	kg PM2.5 eq	3.91E-04	6.09E-05	4.89E-07	0	0	0	0	0	0	0	0	1.78E-05	0	8.23E-06	**4.78E-04**

Variations

The thirteen different processing facilities use different types and amounts of raw materials. The processing facilities also use different amounts of electricity and ancillary materials when operating the plant. The amount of insulation disposed of at end of life varies with each facility as well. Variability was assessed by comparing the lowest and highest values from the companies with the weighted average of all the companies for each impact.

There is a variation greater than 20% because of the differences in all the modules for each product of the participating companies. The companies have different manufacturing procedures for their products, different raw materials and mass composition for the raw materials, different transportation distances and methods etc. The variation essentially depicts the differences between the companies. A greater variation effects the results by making them more variable.

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 to certain chemicals such as boric acid and ammonium sulfate. This could be due to high mass content of those ingredients.

When comparing average total single score results with individual manufacturer total single score results the data shows that 15% of manufacturers fall within the average total mPts, 30% fall above, and 55% fall below.

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, B1-B7	C2	C4	
SM single figure score	mPts	**4.03E-05**	**8.49E-06**	**1.83E-07**	**2.48E-06**	**7.39E-07**	**5.22E-05**

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 was 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 as appropriate). Identifying which choices or assumptions influence the results in any environmental parameter by more than 20% shall be reported. The previous section includes the variations within the product groups. All phases have significant variation due to the process facilities and raw materials used. The sensitivity analysis shows results have greater than 20% variation, this is why they are depicted in red; this variation describes the differences in processes

5.4 Uncertainty analysis

An uncertainty analysis was used to determine the accuracy of the LCA results based on chosen data sets. This analysis is displayed below as a range at a given level of confidence. A confidence interval of 95% was used in this study.

The uncertainty analysis was obtained by running a Monte Carlo analysis in SimaPro for each CIMA participant. The Monte Carlo results were then converted from yearly outputs to the functional unit. The results were averaged for all the companies to provide the uncertainty analysis range for the environmental impacts used for comparison (global warming, acidification, and smog). If a manufacturer's environmental impact lies within the range, it is determined to be equivalent to the industry-wide environmental impact. If a manufacturer's environmental impact lies below the range, it is determined to have a lower environmental impact than the industry-wide impact. If the manufacturer's environmental impact lies above the range, it is determined to have a higher environmental impact than the industry-wide impact.

Three impact categories are used for comparison for conventional loose-fill insulation: global warming, acidification, and smog. The average mean for global warming potential is 7.04E-01 kg CO2 eq (95% confidence interval equals 6.39E-01-7.85E-01 kg CO2 eq). The average mean for acidification potential is 4.43E-03 kg SO2 eq (95% confidence interval equals 3.71E-03-5.40E-03 kg SO2 eq). The average mean for smog potential is 5.24E-02 kg O3 eq (95% confidence interval equals 4.32E-02-6.58E-01 kg O3 eq). With these results the variability in the data an be seen; roughly 15% of the manufacturers fall within the average, 30% fall above the average, and 55% fall below the average.

Calculations were done to verify that the products involved in the study differed in their environmental impact indicators within a 10% range. These caluclations were done by calculating percent difference between impact categories for each manufactuerer and the average impacts.

5.5 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 as well as lower capacity utilization rates.

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 installtion 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.

5.6 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 SimaPro Analyst 8.5.2.0. 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 CIMA's production in the US and Canada. 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.

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

5.8 Conclusions, limitations, and recommendations

The goal of this study was to conduct a cradle-to grave LCA on conventional loose-fill cellulose insulation products so as to develop an industry-wide 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. This is an important area for the CIMA manufacturers to focus its efforts and one which it can influence. CIMA companies can potentially reduce their manufacturing impacts by decreasing electricity in the manufacturing facilities. 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.

Limits of the reported results and methodology are that they are only representative of the industry average; individual results are not displayed and therefore comparisons cannot be made between manufacturers. The methodology and results lead to an overall picture of the industry; however, if manufacturers would like a deeper dive into how their individual products have an impact, it is recommended that they consider a products specific EPD. With this, manufacturers can better understand their own product relative to the average; they can see if they performed better or worse than the average. Meaning that opportunities for change and improvement will be different for each manufacturer. Industry average EPDs are great to get a big picture of a market, but a product specific EPD could provide a more competitive edge to those who are focusing on improving their own products.

6 SOURCES

[1] Cellulose.org. (2019). CIMA: Learn more about the mission and members of the Cellulose Insulation Manufacturers Association. [online] Available at: https://www.cellulose.org/Cellulose-Insulation-2nd.php?pagename=AboutCIMA&dirname=CIMA [Accessed 3 Jul. 2019].

[2] UL Environment, Product Category Rules for preparing an Environmental Product Declaration (EPD) for the Product Category: Part B: Building Envelope Thermal Insulation, v2.0, UL, 2018.

[3] "LCA results spreadsheets", Sustainable Minds, July 3, 2019.

[4] "Primary data spreadsheets", Sustainable Minds, July 2019.

[5] "CIMA_correspondence_documentation.pdf", Sustainable Minds, July 3, 2019.

[6] ISO 14025, "Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures", ISO14025:2006

[7] ISO 14044, "Environmental management - Life cycle assessment - Requirements and guidelines", ISO14044:2006

[8] ISO 21930, "Sustainability in buildings and civil engineering works- Core rules for environmental product declarations of construction and product services", ISO 21930:2017

[9] EN15804, "Sustainability of construction works. Environmental product declarations. Core rules for product category of construction products", EN

[10] North American Electric Reliability Corporation (NERC) , https://www.nerc.com/Pages/default.aspx

[11] eGRID:2 http://www.epa.gov/cleanenergy/energy-resources/egrid

[12] Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., and Weidema, B., 2016. The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, [online] 21(9), pp.1218–1230. Available at: <http://link.springer.com/10.1007/s11367-016-1087-8> [Accessed 01 10 2019]

[13] SimaPro 9.0.0.49

[14] Joep Meijer, Sustainable Minds SM2013 Methodology and Database, April 25, 2013. For a summary, see the Sustainable Minds single score page: http://www.sustainableminds.com/showroom/shared/learn-single-score.html

[15] Bare, J. 2014. Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) TRACI version 2.1 User's Guide. US EPA Office of Research and Development, Washington, DC, EPA/600/R-12/554, http://nepis.epa.gov/Adobe/PDF/P100HN53.pdf

[16] Ryberg, M., Vieira, M.D.M., Zgola, M. et al. (2014). 'Updated US and Canadian normalization factors for TRACI 2.1.' Clean Technologies and Environmental Policy 16: 329. doi:10.1007/s10098-013-0629-z

[17] Gloria, T. P., B. C. Lippiatt & J. Cooper (2007). 'Life cycle impact assessment weights to support environmentally preferable purchasing in the United States.' Environmental Science & Technology, 41(21), 7551-7557

[18] "ACLCA guide to ISO 21930 metrics.xlsx", draft by ACLCA PCR committee working group for ISO 21930 metric calculation guidance, April 2018.

ACRONYMS

ISO	International Standardization Organization
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact analysis
PCR	Product Category Rule document
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 – CIMA_LCIA_results
- LCA results – CIMA_LCI_results
- Primary data_CIMA_Mastersheet_primarydata