LIFE CYCLE ASSESSMENT (LCA) OF HAVELOCK WOOL BATT AND LOOSE-FILL INSULATION

Status	Final
Client	Havelock Wool
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Author(s)	Manuela Toro, LCA Analyst, Sustainable Minds

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1 INTRODUCTION

1.1 Opportunity

Havelock Wool sources a particular blend of fibers for their wool insulation; it is sheared from a specific breed of sheep optimal for insulation. Through high quality wool fibers and proprietary manufacturing processes, a uniform, high-performance, long-lasting product is produced. In line with their commitment to quality and sustainability, it is important that Havelock conduct a Life Cycle Assessment (LCA) to evaluate the environmental impacts of their products through all stages of the life cycle. This project will allow Havelock Wool to assess their products for environmental and human health impacts to identify areas of improvement and product solutions.

In order to understand the total impact of the product through life cycle stages, Havelock Wool is taking a cradle-to-grave approach in conducting this LCA. By including all stages, more information becomes available for understanding how to reduce impacts on a broader scale.

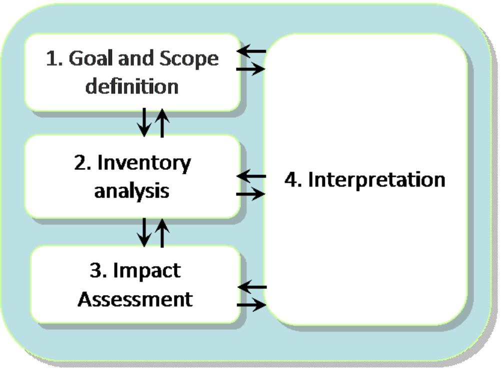
Havelock is interested in having LCA data available for its most common products to be able to obtain a Sustainable Minds Transparency Report™, a Type III Environmental Declaration that can be used for communication with and amongst other companies, architects and consumers and can be utilized in whole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

Havelock commissioned Sustainable Minds to develop LCAs for their insulation products to learn from the results and is looking forward to having guidance for future product improvements that can be deduced from the results.

1.2 Life Cycle Assessment

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

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



Source: ISO 14040

An ISO 14040-44 third-party LCA review and a third-party report verification are required for Type III Environmental Declarations. Both will be completed in this project.

1.3 Status

All information in this report reflects the best possible inventory by Havelock Wool at the time it was collected. Sustainable Minds and Havelock Wool employees conducted best practices to transform this information into this LCA report. The data covers annual production data from 2019 fiscal year from Havelock's manufacturing location in Reno, NV. Where data was missing, assumptions were made from manufacturing data for this facility based upon expertise from Havelock employees.

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

The LCA review and Sustainable Minds Transparency Report / EPD verification will be performed by WAP Sustainability Consulting 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.
From Havelock Wool:

- Andrew William Legge, Founder and Managing Partner of Havelock Wool.
- Peter Blanchard, Director of Sustainability and Finance

From Sustainable Minds:

- Manuela Toro, LCA Analyst

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.

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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 Havelock Insulation products. It is intended for both internal and external purposes. The intended audience includes the program operator (Sustainable Minds) and reviewers who will be assessing the LCA for conformance to the PCRs, as well as Havelock internal stakeholders involved in marketing and communications, operations, and design. Target group, i.e. whether the information and data for an Type III environmental declaration is intended for business-to-business (B2B) and/or business-to-consumer (B2C) communication. Results presented in this document are not intended to support comparative assertions within this study. However, the results will be disclosed to the public in a Sustainable Minds Transparency Report / EPD (Type III environmental declarations per ISO 14025).

2.2 Insulation Products

Havelock is one of the fastest growing manufacturers of sheep wool insulation in the US. The company is interested in demonstrating its leadership in sustainability and continuing its effort to be transparent about the process. This cradle to grave report will further that effort. For more information on Havelock sheep wool insulation products, go to https://havelockwool.com/

The products studied in this report and their manufacturing location is listed in Table 2.2a. The declaration names with products represented and type of declaration, and other product information for each product are listed in Tables 2.2b and 2.2c, respectively.

Table 2.2a Product names and manufacturing location

Product name	Manufacturing location
Wool Batt Insulation	Reno, NV
Loose Fill Insulation	Reno, NV

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

Transparency Report	Product name	Type of declaration
Wool Batt Insulation	Wool Batt Insulation	One specific product from manufacturer’s plant
Loose Fill Insulation	Loose Fill Insulation	One specific product from manufacturer’s plant

Table 2.2c Other product information

Transparency Report name	CSI MasterFormat® classification	Application	ASTM or ANSI product specification
Wool Batt Insulation	**07 21 00**	Havelock has applied carding technology to conventional batt insulation. Historically batts were made with toxic bonding agents necessary to create a low-cost insulating product with some ability to maintain shape. Havelock Wool batts are made with 100% wool, no synthetic mix,	**ASTM C-518** **E-84** **C-423**

		and are bonded with a needle punch, not chemicals. Unlike other forms of insulation Havelock Wool batts are easy to handle. They do not require protective clothing or safety equipment like respirators, gloves or heavy clothing to install: they are safe to the touch. These characteristics have earned them the label as the ultimate in DIY for home insulation.	
Loose Fill Insulation	**07 21 23**	Loose fill insulation is increasingly preferred amongst industry leaders in the built environment. Havelock Wool Loose Fill insulation is widely used in residential and commercial construction applications that require superior thermal, moisture and acoustic insulation. Havelock Wool produces loose fill following a proprietary and repeatable manufacturing process. This yields knops, or balls, that enhance our wool's ability to trap air. This process accelerates wool's inherent characteristics and allows us to exceed the R-values of all other insulation mediums save spray foam.	**ASTM C-518** **E-84** **C-423**

2.3 Functional Unit

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

1 m2 of installed insulation material with a thickness that gives an average thermal resistance RSI = 1 m2·K/W and with a building service life of 75 years (packaging included)

Building envelope thermal insulation is assumed to have a reference service life equal to that of the building, which in this case is 75 years [1]. The insulation does not need to be replaced, and 1 m2 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 RSI = 1 m2·K/W, which varies for each product. Reference flows are listed in Table 2.3a.

Table 2.3a Reference flows

Product	Insulation (kg)	Packaging (kg)	Thickness at RSI=1 (m)	Reference flow total (kg per m^2)
Wool Batt Insulation	81259.2	1090.5	.04043	.9971
Loose Fill Insulation	41860.8	561.8	.04027	.6071

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. 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:

I. **A1-A5**
  - Raw materials acquisition, transportation, and manufacturing
  - Distribution and installation

II. **B1-B7**
  - Use

III. **C1-C4**
  - Disposal/reuse/recycling

These boundaries apply to the modeled products and can be referred to as 'cradle-to-grave', which means that it includes all life cycle stages and modules as identified in the PCRs [1]. The system boundaries for Havelock Wool products are detailed below. Figure 2.4a represents the life cycle stages for the entire life cycle of these products. Table 2.4a lists specific inclusions and exclusions for the system boundaries.

Figure 2.4a Applied system boundaries for the modeled insulation products

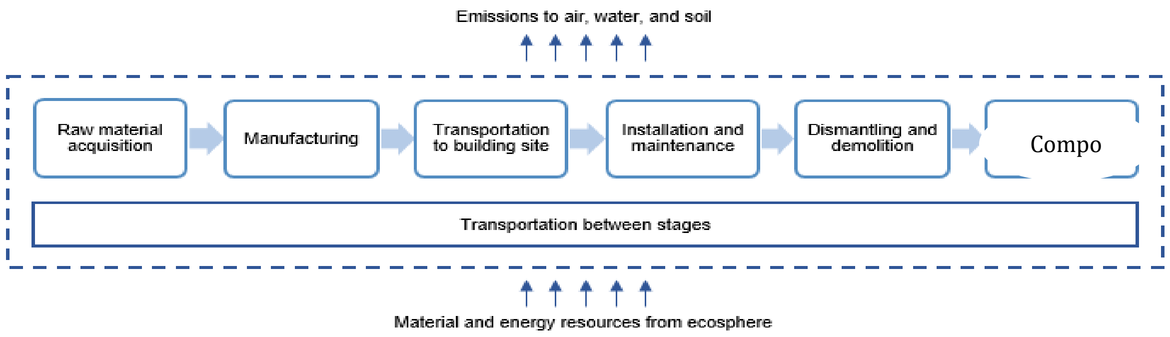


Table 2.4a System boundaries

Included	Excluded
• Raw material acquisition as a waste byproduct • Processing of raw materials • Energy production • Transport of raw materials • Transport of wet boric acid • 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	• Sheep husbandry intended for meat production • Meat production of sheep • Evaporation of water from wet boric acid • 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 not associated with product manufacturing

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

Raw materials acquisition and transportation (A1-A2) These stages include, where relevant, the following processes:

- Transportation of wet boric acid to scouring facility
- Extraction and processing of raw materials: scouring and addition of dry boric acid to wool
- 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) This stage includes:

- Manufacturing of sheep wool 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) This 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

Name	Value	Unit
Fuel type	Diesel	-
Liters of fuel	Unkown	-
Vehicle type	Truck-16T	-
Transport distance	2704.73	km
Weight of products transported	57,000	kg/yr

Installation (A5) This stage includes:
- 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. 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

Name	Value	Unit
Ancillary materials	-	-
Other resources	-	-
Gas	1585.73	Liters/yr
Waste materials at the construction site before waste processing, generated by product installation	7524	kg/yr
Biogenic carbon contained in packaging	-	-

2.4.3. **B1-B7: Use** This stage includes:
- Product use
- Maintenance
- Repair
- Replacement
- Refurbishment
- Operational energy use
- Operational water use

Name	Value	Unit
RSL	75	years
Declared product properties (at the gate) and finishes, etc…	100% wool	_
An assumed quality of work when installed in accordance with manufacturer's instructions	High	_
Indoor environment (if relevant for indoor applications), e.g. temperature, moisture, chemical exposure	Residential use	_
Use conditions, e.g. frequency of use, mechanical exposure	Installed once for the span of RSL	_
Maintenance, e.g. required frequency, type and quality of replacement components	_	_

2.4.4. C1-C4: Disposal/reuse/recycling

Deconstruction (C1) This stage includes dismantling/demolition.

Transport (C2) This stage includes transport from building site to final disposition.

Waste processing (C3) This stage includes processing required before final disposition.

Disposal (C4) This stage includes final disposition (e.g. recycling/reuse/landfill/waste incineration/conversion to energy).

Name	Value
Assumptions for scenario development (description of deconstruction, collection, recovery, disposal method and transportation)	Individuals are assumed to take product to nearest composting facility.
Collection process (specified by type)	Unknown
Recovery (specified by type)	Compost
Disposal (specified by type)	Wool

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 catalogs the flows crossing the system boundary and provides the starting point for life cycle impact assessment, see the attached spreadsheets [2].

3.1 Data Collection

Data used for this project represents a mix of primary data collected from Havelock [3] on the production of the insulation products (gate-to-gate) and background data from SimaPro 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 Havelock Wool. Data were collected at its Reno, NV facility.

- **Background data:** All data from SimaPro were created with consistent system boundaries and upstream data. Expert judgment and advice was used in selecting appropriate datasets to model the materials and energy for this study and has been noted in the preceding sections. Detailed database documentation for ecoinvent can be accessed at: https://www.ecoinvent.org/database/database.html.

All primary data were provided by Havelock. 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 Havelock to resolve any open issues.

3.2 Primary Data

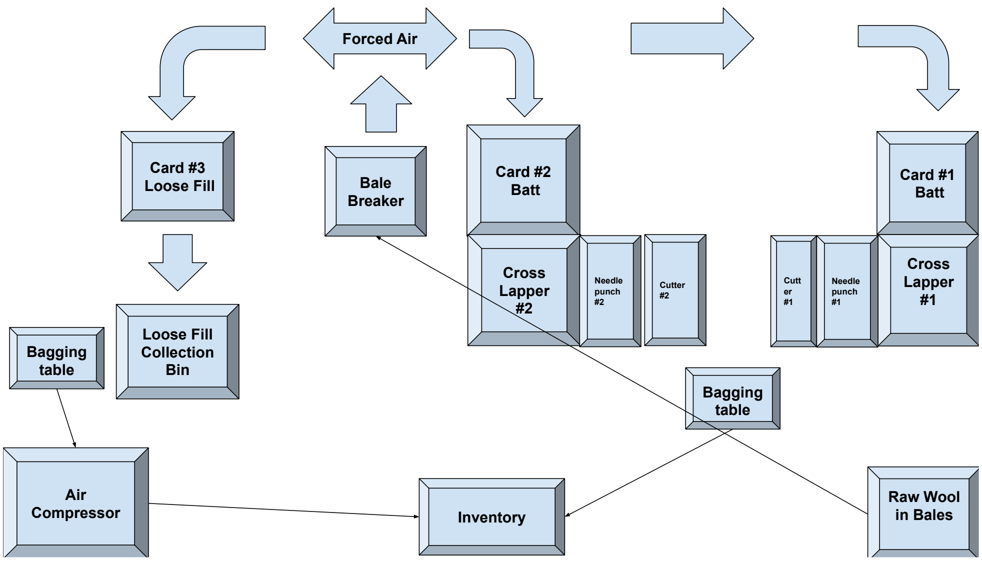
The Wool Batt and Loose Fill Insulation systems are produced in several manufacturing steps that involve processing the sheep wool fibers.

The steps that involve manufacturing the wool into insulation include scouring, carding, needle punching, cutting, and bagging.

The finished products are then distributed to construction sites where the wool is installed, and the packaging is disposed (sent to landfill or recycled). Building envelope thermal insulation has a 75-year reference service life this can be longer which is equal to that of the building. At end of life, the insulation is removed and is composted. The flow charts in Figure 3.2a illustrate the life cycle of the insulation products.

Data used in this analysis represent insulation production at Havelock. Results were then scaled to reflect the functional unit.

Figure 3.2a Life cycle flow chart of insulation products production



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

Raw materials acquisition and transportation represents the first stage of the insulation products' life cycle. The wool used by Havelock Wool is the waste wool that results from the meat production industry in New Zealand. In other words, the wool procured by Havelock is byproduct wool. Due to this, sheep husbandry will not be included in this analysis. Wool is procured at a live auction in New Zealand and then is transported to the scour where it is cleaned and where boric acid is applied. Raw material inputs for the products are listed in tables 3.2a & b.

Assumptions were made regarding the wool dataset; a custom dataset was created to reflect the wool energy consumption during the shearing and scouring process while excluding sheep husbandry. Chemicals used during scouring were excluded due to inability to find datasets to accurately represent those chemicals. These assumptions were made based on LCA done in New Zealand on wool shearing and scouring processes [11].

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 [4].

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 Havelock Wool's facility via ocean freight and truck & trailer. Transport data were collected for each flow and are shown in table 3.2a & b for transportation to Reno, NV.

Table 3.2a Wool Batt Insulation

Flow	Mass percentage	Transportation	Distance (km)
Raw wool	97.85%	Ocean freight	10, 591
Boric acid	.734%	Truck and trailer, 16T	340
Steel Straps	1.18%	Ocean freight	10, 591
Nylon bale wrap	0.236%	Ocean freight	10, 591

Table 3.2a Wool Loose Fill Insulation

Flow	Mass percentage	Transportation	Distance (km)
Raw wool	97.85%	Ocean freight	10, 591
Boric acid	.734%	Truck and trailer, 16T	340
Steel straps	1.18%	Ocean freight	10, 591
Nylon bale wrap	0.236%	Ocean freight	10, 591

3.2.2. Manufacturing (A3)

After the raw materials are transported to Havelock's facility, the bales are offloaded and stored before processing. There is a steel strapping and nylon bale wrap that protects the wool during transport to the facility so they must be run through the bale breaker before being processed.

Once the bales are opened, they are run through a loose wool opening machine and distributed to a designated production line via air and overhead ducting. There is a single loose-fill production line and two identical batt production lines. During both production processes, the wool is first carded, meaning it is broken up from being in unorganized clumps.

The loose fill production line is the least complex. Wool is delivered to the carding machine via air duct. The loose fill carding machine has rollers that run in a specific manner which allows for the creation of nice wool balls (loose fill). In this final state, the wool goes up another air vent and into a big collection bin ready to be bagged.

The batt production has a few additional steps. The carding machine creates a thin film of wool which is cross-lapped or layered on itself. Next, it is needle punched. The sheet is then processed through a series of cutters where it is cut in appropriate dimensions for use as insulation.

Annual manufacturing inputs and outputs for the remaining products are shown in Tables 3.2.2a & b. Emissions associated with the production of electricity and the combustion of natural gas are accounted for in the ecoinvent background processes.

Table 3.2.2a Wool Batt Insulation

	Flow	Amount	Unit/yr
Inputs	Electricity	164,615	kWh
	Water	28470	gal
	Lubricating oil	480.5	fl Oz
Outputs	Polyester bags	6810	kg
	Wool dust	2802	kg
	Steel straps	3580	kg
	Nylon bale wraps	715.9	kg

Table 3.2.2b Wool Loose Fill Insulation

	Flow	Amount	Unit
Inputs	Electricity	84802	kWh
	Lubricating oil	247.5	fl Oz
Outputs	Polyester bags	20163	kg
	Wool dust	1443.3	kg
	Steel straps	1844.2	kg
	Nylon bale wraps	368.8	kg

3.2.3. Distribution (A4)

Products are packaged in the manufacturing plant and shipped directly to distributors, installers and end-users across the US. A transportation distance of 1,681 miles is assumed based on information provided by Havelock Wool [3]. Based on its records, all products are shipped by truck and trailer. Table 3.2.3 details insulation distribution.

Table 3.2.3 Distribution for insulation products

Product	Value	Unit
Truck and trailer transport		
Wool Batts	1,681	mi
Wool Loose Fill	1,681	mi

3.2.4. Installation (A5)

At the installation site, the Batts and the Loose Fill Insulation uses different processes. The Batts utilize a cutting blade and a staple gun; between 6-8 staples are used for each batt. Loose Fill is installed with a gas blower ~23hp with high fuel efficiency. The tank is 2 gallons and basically burns one per hour in which time 12 bags can installed; meaning roughly 1 bale is installed on 3 gallons of gas. No electricity is used during the installation process.

The plastic packaging of the bales is sent to landfill or recycle. The amount of gas and waste is modeled in Table 3.2.4a.

Table 3.2.4a Gas and waste used one annual production for installation

Product	Gas (liters)	Plastic waste (kg)
Wool Batts	0	5676
Wool Loose Fill	158.7	1848

3.2.5. Use (B1-B7)

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

3.2.6. Deconstruction (C1)

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

3.2.7. Transport (C2)

After removal, the insulation is assumed to be transported 339 miles to a composting site. Determined by max distance using search parameters in the US.

3.2.8. Waste processing (C3)

No waste processing is required before being composted.

3.2.9. Disposal (C4)

After removal, the insulation is assumed to be composted. This assumption is made based on a position paper by the Wool Council attesting to biodegradability and a study by Texas State University that shows compostability of wool products under different conditions.

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 regard to the goal and scope of the study.

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

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

Time coverage. Primary data were collected on insulation production during February 2020. These dates were chosen in order to capture a representative picture of Havelock Wool's products. Background data for upstream and downstream processes (i.e. raw materials, energy resources, transportation, and ancillary materials) were obtained from the ecoinvent databases.

Technology coverage. Data were collected for Havelock Wool's insulation production facility in the US.

Geographical coverage. Havelock Wool's facility is located in Reno, NV. As such, the geographical coverage for this study is based on United States system boundaries for all processes and products. Whenever US background data were not readily available, European data or global data were used as proxies. Following production, insulation is shipped for use within the continental United States. Use and end-of-life impact were modeled using background data that represents average conditions for North America.

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 SimaPro. The grid mixes used for electricity are from the North American Regional Reliability Councils and Interconnections (NERC). For Reno, NV, the WECC electric grid is used. Table 3.4.1 shows the most relevant LCI datasets used in modeling the product systems.

Table 3.4.1 Key energy datasets used in inventory analysis

Energy	Dataset name	Primary source	Reference year	Geography
Electricity	Electricity grid mix – WECC	NERC	2014	US WECC

3.4.2. Raw materials production

Data for up- and down-stream raw materials were obtained from the ecoinvent database. 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	Sheep wool	EI v3	2014	Global
Product	Boric acid	EI v3	2014	Global
Packaging	Steel, low-alloyed	EI v3	2014	Global
Packaging	Nylon, 6	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 and boats.

Table 3.4.4 Key transportation datasets used in inventory analysis

Transportation	Dataset name	Primary source	Reference year	Geography
Truck & trailer	Transport, lorry, 16-32 metric ton	EI v3	2014	Global
Boat	Ocean, freighter, diesel powered	EI v3	2014	Global

3.4.4. Disposal

Disposal processes were obtained from the ecoinvent database. These processes were chosen to correspond to the materials being disposed, which are packaging materials and insulation. The 'biowaste, industrial composting' was used for the final disposal data set for the insulation. Table 3.4.5 reviews the relevant disposal datasets used in the model.

Table 3.4.5 Key disposal datasets used in inventory analysis

Material disposed	Dataset name	Primary source	Reference year	Geography
Plastic bag	Inert waste, for final disposal	EI v3	2014	Global
Product	Biowaste, industrial composting	EI v3	2014	Global

3.4.5. Emissions to air, water, and soil

Havelock Wool reported no emissions to air, water, or soil. There is a machine in the Havelock facility that has a wool dust collector to capture dust, which is then sent to a composting site.

3.5 Limitations

Sheep wool insulation is assumed to have a reference service life equal to that of the building [4]. Thus, for example if the building has a 75-year service life, the insulation is likewise assumed to last 75 years with no maintenance. Although the building envelope thermal insulation PCR requires a functional unit of $R_{SI} = 1\ m^2 \cdot K/W$ [1], Sustainable Minds calculated this figure based on third-party Havelock testing data. The declared product is delivered to the site of installation with the R-value and can be accompanied by third-party testing data.

LCA results for the products represent production volumes for the Reno, NV facility.

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

3.6 Criteria for the exclusion of inputs and outputs

All energy and material flow data available 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 [1].

- 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 judgment 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 PCR prescribes to report where and how allocation occurs in the modeling of the LCA.

No allocation was necessary in this project. Havelock Wool provided data for two different products from one facility. All the data provided was specific to each product.

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 most of the raw materials and processes for modeling the products.

3.9 Critical review

This is a supporting LCA report for wool insulation products Transparency Reports and will be evaluated for conformance to the PCR according to ISO 14025 [5] and the ISO 14040/14044 standards [6].

4 IMPACT ASSESSMENT METHODS

4.1 Impact assessment

The environmental indicators as required by the PCRs are included as well as other indicators required to use the SM2013 Methodology [7] (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 [8]. Long-term emissions (> 100 years) are not taken into consideration in the impact estimate. USEtox indicators are used to evaluate ecotoxicity. Results will be reported only as a contribution analysis which follows the approach from the PCR.

Table 4.1 Selected impact categories and units

Impact category	Unit
Acidification	kg SO2 eq (sulphur dioxide)
Ecotoxicity	CTUe
Eutrophication	kg N eq (nitrogen)
Global warming	kg CO2 eq (carbon dioxide)
Ozone depletion	kg CFC-11 eq
Carcinogenics	CTUh
Non-carcinogenics	CTUh
Respiratory effects	kg PM2.5 eq (fine particulates)
Smog	kg O3 eq (ozone)
Fossil fuel depletion	MJ surplus

With respect to global warming potential, biogenic carbon is included in impact category calculations.

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

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

4.2 Normalization and weighting

To arrive to a single score indicator, normalization [9] and weighting [10] conforming to the SM 2013 Methodology were applied.

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

Table 4.2 Normalization and weighting factors

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

5 ASSESSMENT AND INTERPRETATION

This chapter includes the results from the LCA for the products studied. It details the results per product per functional unit and concludes with recommendations. LCI and LCIA data can be seen in the LCA results spreadsheets [2]. The results are presented per functional unit.

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 [11].

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.

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 composted rather than incinerated or reused/recycled.

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

Table 5.1a Resource use, output and waste flows, and carbon emissions and removals for Wool Batt Insulation per functional unit [2]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
Resource use indicators															
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	6.38E+00	8.79E-03	7.86E-06	0	0	0	0	0	0	0	0	1.83E-03	0	3.24E-03
Renewable primary resources with energy content used as material	MJ, LHV	1.96E+01	1.46E-02	2.04E-05	0	0	0	0	0	0	0	0	4.60E-02	0	4.60E-02
Total use of renewable primary resources with energy content	MJ, LHV	2.60E+01	2.34E-02	2.83E-05	0	0	0	0	0	0	0	0	4.82E-03	0	4.93E-02
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	4.57E+01	7.47E+0 0	1.15E+0	0	0	0	0	0	0	0	0	1.66E+00	0	4.17E-01
Non-renewable primary resources with energy content used as material	MJ, LHV	2.68E-03	2.18E-05	1.05E-07	0	0	0	0	0	0	0	0	4.57E-06	0	1.10E-05
Total use of non-renewable primary resources with energy content	MJ, LHV	4.57E+01	7.47E00	1.15E+0	0	0	0	0	0	0	0	0	1.66E+00	0	4.17E-01
Secondary materials	kg				0	0	0	0	0	0	0	0		0	
Renewable secondary fuels	MJ, LHV	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
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Use of net fresh water resources	m3	4.01E-01	4.33E-03	3.87E-04	0	0	0	0	0	0	0	0	9.46E-04	0	8.75E-02
Output flows and waste category indicators															
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0
High-level radioactive waste, conditioned, to final repository	kg	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
Components for re-use	kg	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
Materials for energy recovery	kg	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
Carbon emissions and removals															
Biogenic Carbon Removal from Product	kg CO_2		0	0	0	0	0	0	0	0	0	0	0	0	0
Biogenic Carbon Emission from Product	kg CO_2	2.71E-01	0	3.72E-05	0	0	0	0	0	0	0	0	1.32E-04	0	1.44E-01
Biogenic Carbon Removal from Packaging	kg CO_2	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
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
Calcination Carbon Emissions	kg CO_2	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
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

Table 5.1b Resource use, output and waste flows, and carbon emissions and removals for Wool Loose Fill Insulation per functional unit [2]

	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
Resource use indicators															
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	2.16E+00	5.94E-03	1.58E-05	0	0	0	0	0	0	0	0	1.20E-03	0	2.12E-03
Renewable primary resources with energy content used as material	MJ, LHV	6.63E+00	9.76E-03	4.11E-05	0	0	0	0	0	0	0	0	1.97E-03	0	3.02E-02
Total use of renewable primary resources with energy content	MJ, LHV	8.78E+00	1.57E-02	5.70E-05	0	0	0	0	0	0	0	0	3.17E-03	0	3.23E-03
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	1.70E+01	5.39E+0 0	7.63E-01	0	0	0	0	0	0	0	0	1.09E+00	0	2.74E-01
Non-renewable primary resources with energy content used as material	MJ, LHV	9.07E-04	1.49E-05	2.11E-07	0	0	0	0	0	0	0	0	3.00E-06	0	7.25E-06
Total use of non-renewable primary resources with energy content	MJ, LHV	1.70E+01	5.39E+0 0	7.63E-01	0	0	0	0	0	0	0	0	1.09E00	0	2.74E-01
Secondary materials	kg		0	0	0	0	0	0	0	0	0	0	0	0	0
Renewable secondary fuels	MJ, LHV	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
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Use of net fresh water resources	m3	2.53E-01	2.88E-03	1.10E-03	0	0	0	0	0	0	0	0	5.76E-04	0	5.74E-02
Output flows and waste category indicators															
Hazardous waste disposed	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-hazardous waste disposed	kg	0	0		0	0	0	0	0	0	0	0	0	0	
High-level radioactive waste, conditioned, to final repository	kg	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
Components for re-use	kg	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
Materials for energy recovery	kg	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
Carbon emissions and removals															
Biogenic Carbon Removal from Product	kg CO_2		0	0	0	0	0	0	0	0	0	0	0	0	0
Biogenic Carbon Emission from Product	kg CO_2	1.40E-01	6.55E-04	3.97E-05	0	0	0	0	0	0	0	0	1.32E-04	0	1.44E-01
Biogenic Carbon Removal from Packaging	kg CO_2	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
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
Calcination Carbon Emissions	kg CO_2	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
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

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 Havelock Wool's insulation products. Unlike life cycle inventories, which only report sums for individual inventory flows, the LCIA includes a classification of individual emissions with regard to the impacts they are associated with and subsequently a characterization of the emissions by a factor expressing their respective contribution to the impact category indicator. The end result is a single metric for quantifying each potential impact, such as 'global warming potential.'

The impact assessment results are calculated using characterization factors published by the United States Environmental Protection Agency. The TRACI 2.1 (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts 2.1) methodology is the most widely applied impact assessment method for U.S. LCA studies. USEtox indicators are used to evaluate ecotoxicity, results will be reported only as a contribution analysis. The SM 2013 Methodology is also applied to come up with single score results for the sole purpose of representing total impacts per life cycle phase to explain where in the product life cycle greatest impacts are occurring and what is contributing to the impacts.

The six impact categories required by the PCR are globally deemed mature enough to be included in Type III environmental declarations. Other categories are being developed and defined and LCA should continue making advances in their development; however, the EPD users shall not use additional measures for comparative purposes. There are several impact categories included in the SM 2013 Methodology not required by the PCR, 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. Sheep Wool Batt Insulation

Tables 5.2.1a shows the contributions of each stage of the life cycle.

For this insulation, the top three impact categories are ecotoxicity, fossil fuel depletion and global warming potential. The raw material acquisition and manufacturing stages (A1-A3) dominate the results for all impact categories.

Following these two stages, the next highest impacts come from the transportation stage (A4), which have a lower contribution. The impact of the raw material acquisition and manufacturing stages are mostly due to the processing, transportation and manufacturing raw materials/product. Scouring is the process of removing the impurities from the wool and is a process that uses electricity, heat and water. The fuel consumed and emissions associated with transportation and the energy used during manufacturing all contribute to A1-A3 impacts.

The contributions to outbound transportation are caused by the use of trucks. The impacts associated with installation and maintenance are due to the disposal of packaging waste and the installation consumes gas. The end of life of the product is impacted by transportation to the composting site.

Table 5.2.1a Wool Batt Insulation impact potential results per functional unit [2]

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
Acidification	kg SO_2 eq	1.37E-02	1.71E-03	6.17E-04	0	0	0	0	0	0	0	0	4.90E-04	0	1.83E-03
Eutrophication	kg N eq	2.79E-03	2.05E-04	3.64E-05	0	0	0	0	0	0	0	0	5.24E-05	0	8.12E-05
Global warming	kg CO_2 eq	2.63E+00	3.62E-01	5.33E-02	0	0	0	0	0	0	0	0	8.11E-02	0	4.17E-02
Ozone depletion	kg CFC-11 eq	1.84E-07	7.07E-08	8.19E-11	0	0	0	0	0	0	0	0	1.59E-08	0	3.48E-09
Carcinogenics	CTUh	1.17E-07	4.60E-09	8.84E-10	0	0	0	0	0	0	0	0	9.41E-10	0	7.77E-10
Non-carcinogenics	CTUh	4.00E-07	2.87E-08	8.48E-09	0	0	0	0	0	0	0	0	5.92E-09	0	3.07E-09
Respiratory effects	kg PM2.5 eq	5.04E-03	1.13E-04	1.01E-05	0	0	0	0	0	0	0	0	2.88E-05	0	5.64E-05
Smog	kg O_3 eq	2.91E-01	4.39E-02	1.88E-02	0	0	0	0	0	0	0	0	1.37E-02	0	1.52E-03
Fossil fuel depletion	MJ, LHV	3.09E+00	7.31E-01	1.23E-01	0	0	0	0	0	0	0	0	1.64E-01	0	3.26E-02

Additional environmental information	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
Freshwater ecotoxicity	%	90.57%	4.69%	3.44%	0	0	0	0	0	0	0	0	.96%	0	0.33%

Single score results

The SM 2013 Methodology single figure millipoint (mPts) 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.

Table 5.2.1b SM 2013 scores for Wool Batt Insulation by life cycle stage per functional unit [2]

Impact category	Unit	Raw material acquisition and manufacturing	Transportation	Installation and maintenance	Transportation	Disposal
		A1-A3	A4	A5, B1-B7	C2	C4
SM single figure score	mPts	**3.83E-04**	**2.58E-05**	**6.10E-06**	**5.76E-06**	**3.90E-06**

5.2.2. Sheep Wool Loose Fill Insulation

Table 5.2.2a shows the contributions of each stage of the life cycle.

For this insulation, the top three most impacted categories for loose fill are ecotoxicity, fossil fuel depletion and global warming potential. The raw material acquisition and manufacturing stages (A1-A3) dominate the results for all impact categories. Following these stages, the next highest impacts come from the transportation to distribution stage (A4), which has lower contribution. The impact of the raw material acquisition and manufacturing stages are mostly due to the processing, transportation and manufacturing raw materials/product. Scouring is the process of removing the impurities from the wool and is a process that uses electricity, heat and water. The fuel consumed and emissions associated with transportation and the energy used during manufacturing all contribute to A1-A3 impacts.The contributions to outbound transportation are caused by the use of trucks. The impacts associated with installation and maintenance are due to the disposal of packaging waste and the installation consumes gas. The end of life of the product is impacted by transportation to the composting site.

Table 5.2.2a Sheep wool loose-fill impact potential results per functional unit [2]

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
Acidification	kg SO2 eq	1.13E-02	2.87E-03	7.34E-04	0	0	0	0	0	0	0	0	5.80E-04	0	2.16E-03
Eutrophication	kg N eq	1.88E-03	3.07E-04	4.35E-05	0	0	0	0	0	0	0	0	6.19E-05	0	9.60E-05
Global warming	kg CO2 eq	1.76E+00	4.75E-01	6.36E-02	0	0	0	0	0	0	0	0	9.58E-02	0	4.93E-02
Ozone depletion	kg CFC-11 eq	1.13E-07	9.29E-08	2.91E-10	0	0	0	0	0	0	0	0	1.87E-08	0	4.11E-09
Carcinogenics	CTUh	7.32E-08	5.51E-09	1.05E-09	0	0	0	0	0	0	0	0	1.11E-09	0	9.18E-10
Non-carcinogenics	CTUh	2.65E-07	3.47E-08	1.01E-08	0	0	0	0	0	0	0	0	6.99E-09	0	3.63E-09
Respiratory effects	kg PM2.5 eq	3.12E-03	1.69E-04	1.24E-05	0	0	0	0	0	0	0	0	3.41E-05	0	6.67E-05
Smog	kg O3 eq	2.73E-01	8.05E-02	2.23E-02	0	0	0	0	0	0	0	0	1.62E-02	0	1.79E-03
Fossil fuel depletion	MJ, LHV	2.18E+00	9.59E-01	1.48E-01	0	0	0	0	0	0	0	0	1.93E-01	0	3.86E-02

Additional environmental information	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
Freshwater ecotoxicity	%	84.95%	7.56%	5.45%	0	0	0	0	0	0	0	0	1.52%	0	0.53%

Single score results

The SM 2013 Methodology single figure millipoint (mPts) score by life cycle phase for this product is presented below (Table 5.2.2b). They do not conflict with the trends in the results using the impact assessment results before normalization and weighting.

Table 5.2.2b SM 2013 scores for Loose Fill Insulation by life cycle stage per functional unit [2]

Impact category	Unit	Raw material acquisition and manufacturing	Transportation	Installation and maintenance	Transportation	Disposal
		A1-A3	A4	A5, B1-B7	C2	C4
SM single figure score	mPts	**2.51E-04**	**3.37E-05**	**7.25E-06**	**6.80E-06**	**4.61E-06**

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 and the manufacturing stages (A1-A3). The impacts in these stage are due to the processing and transportation of raw materials to facility in Reno, NV and the manufacturing of the final insulation products.

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

Installation accounts for a small fraction of overall life cycle impact, only gasoline is used during installation of the product, the impacts are very low. 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 composted. For all products, transportation to end of life sites was the greatest contributor to impacts in this stage. Non-hazardous waste also accounts for waste generated during manufacturing (wool dust).

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 SimaPro Analyst 8.5.2.0. The ecoinvent LCI 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: Reproducibility is warranted as much as possible through the disclosure of input-output data, dataset choices, and modeling approaches in this report. Based on this information, any third party should be able to approximate the results of this study using the same data and modeling approaches.

Representativeness

- Temporal: All primary data were collected for January 2019 through December 2019 in order to ensure representativeness of post-consumer content. All secondary data were obtained from the ecoinvent databases and are typically representative of the years 2008 – 2014.

- Geographical: Primary data are representative of Havelock Wool's production in the US. 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.

5.5 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). Identifying which choices or assumption influence the results in any environmental parameter by more than 20% shall be reported. The previous section includes the variations within the product groups. All phases have significant variation due to the process facilities and raw materials used.

Different end-of-life scenarios were compared: compost vs landfill and it was found that in both cases, the overall impacts due to end-of-life scenarios are negligible. The contribution of end of life scenario is less than 10% of overall impacts, therefore holds little significance.

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 Havelock Wool Insulation products so as to develop an SM Transparency Report / EPD. The creation of these Transparency Reports will allow consumers in the building and construction industry to make better informed decisions about the environmental impacts associated with the products they choose. Overall, the study found that environmental performance is driven primarily by cradle-to-gate impact. Raw material acquisition and manufacturing (A1-A3) emissions 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 (A1-A3). The impacts in the stage are largely due to transportation from raw material acquisition site to the plant. This is an important area for Havelock to focus its efforts and one which it can influence.

6 Sources

[1] 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.

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

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

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

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

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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 / EPD™
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 – Havelock_LCI
- LCA results – Havelock_LCIA
- Primary data – Havelock_products