POLYISOCYANURATE INSULATION MANUFACTURERS ASSOCIATION

ENVIRONMENTAL PRODUCT DECLARATION

Polyiso Wall Insulation Boards

For more than 30 years, the Polyisocyanurate Insulation Manufacturers Association (PIMA) has served as the voice of the North American rigid polyiso industry, and as a proactive advocate for safe, cost-effective, sustainable, and energy-efficient high-performance building construction. PIMA is one of the foremost industry advocates for building energy-efficiency practices and policies.

PIMA membership includes manufacturers of polyiso insulation products, raw material suppliers to the industry, and businesses that provide third-party testing services to manufacturers. PIMA members produce the majority of polyiso used in commercial roof and wall applications, and residential, institutional and industrial construction throughout the United States and Canada. PIMA represents the rigid polyiso industry in the development of product technical standards, certification programs, and energy efficiency advocacy.

As a leading advocate for building energy efficiency, PIMA has received many environmental awards, including the U.S. Environmental Protection Agency's Climate Protection Award in 2007 for the Association's leadership in promoting energy efficiency and climate protection. The U.S. EPA also awarded PIMA the Stratospheric Ozone Protection Award in 2002 for leadership in the CFC phase-out in polyiso insulation and in recognition of exceptional contributions to global environmental protection.

Date of Issue: November 4, 2020
Period of Validity: 5 years
Declaration Number: EPD10466

Certified Environmental Product Declaration
www.nsf.org

Primary data from the following PIMA manufacturer members were used for the underlying life cycle assessment. Results in this declaration represent the combined weighted average production for these members.

Atlas Roofing Corporation
2000 River Edge Parkway, Suite 800
Atlanta, GA 30328
www.atlasroofing.com

Carlisle Construction Materials
1285 Ritner Highway
Carlisle, PA 17013
www.carlisleconstructionmaterials.com

Firestone Building Products
200 4th Avenue South
Nashville, TN 37201
www.firestonebpco.co

GAF
1 Campus Drive
Parsippany, NJ 07054
www.gaf.com

IKO
40 Hansen Road South
Brampton, Ontario, Canada L6W 3H4
www.iko.com

Johns Manville
717 17th Street
Denver, CO 80202
www.jm.com

Rmax - A Sika Brand
13524 Welch Road
Dallas, TX 75244
www.rmax.com

Soprema, Inc. (USA)
310 Quadral Drive
Wadsworth, OH 44281
www.soprema.us

Soprema, Inc.
1688 Jean-Berchmans-Michaud
Drummondville, Quebec, Canada J2C 8E9
www.soprema.ca

PIMA manufacturer members provided primary data for products marketed by the following companies.

Carlisle Coatings & Waterproofing
900 Hensley Lane
Wylie, TX 75098
www.carlisleccw.com

Hunter Panels
15 Franklin Street
Portland, ME 04101
www.hunterpanels.com

POLYISOCYANURATE INSULATION MANUFACTURERS ASSOCIATION

GENERAL INFORMATION

EPD Program Operator	NSF Certification, LLC 789 N. Dixboro Road Ann Arbor, Michigan, 48105, USA www.nsf.org
Reference PCR	Product Category Rules for Building-Related Products and Services Part A: Life Cycle Assessment Calculation Rules and Report Requirements (UL 10010, Version 3.2), and Product Category Rule (PCR) Guidance for Building-Related Products and Services Part B: Building Thermal Insulation EPD Requirements (UL10010-1, Version 2.0), and ISO 21930: 2017
Declaration Holder	Polyisocyanurate Insulation Manufacturers Association 3330 Washington Boulevard, Suite 200 Arlington, Virginia, 22201, USA www.polyiso.org
LCA & Declaration Preparer	Shelly Severinghaus, LCACP Long Trail Sustainability 830 Taft Road Huntington, Vermont, 05462, USA www.ltsexperts.com
Declaration Number	EPD10466
Product	Polyisocyanurate Wall Insulation Boards
Intended Applications and Use	Commercial, light commercial, residential and industrial wall construction
Markets of Applicability	United States and Canada
Product RSL Description	75 years
Declared Product & Function Unit	1 m^2 of installed insulation material with a thickness that gives an average thermal resistance R_{SI} = 1 m^2·K/W (5.678 ft^2·°F·h/Btu) and with a building service life of 75 years (packaging included)
PCR Review was Conducted by:	– Part A – UL Technical Advisory Panel – Part B – Thomas Gloria, PhD (chair)
Date of Issue	November 4, 2020
Period of Validity	5 years from date of issue
EPD Type	Industry-average
EPD Scope	Cradle-to-grave
Range of Dataset Variability	Industry-average
Year(s) of Reported Manufacturer Primary Data	2017
LCA Completion	Life Cycle Assessment of Rigid Polyisocyanurate Foam Board Insulation, August 2020
LCA Software & Version Number	SimaPro (Version 9.0.0.35)
LCI Databases & Version Number	ecoinvent v3.5, Cut-off at Classification (ecoinvent centre, 2018), US LCI (NREL, 2015) and DATASMART v2018.1 (Long Trail Sustainability, 2018)
LCIA Methodology & Version Number	TRACI 2.1 version 1.05
This EPD was independently verified by NSF in accordance with ISO 14025: 2006 and ISO 21930: 2017: ❑ Internal ☒ External	Jenny Oorbeck – NSF joorbeck@nsf.org
This life cycle assessment was conducted in accordance with ISO 14044: 2006, reference PCR, and ISO 21930: 2017:	Long Trail Sustainability shelly@ltsexperts.com
This life cycle assessment was independently verified in accordance with ISO 14044: 2006 and the reference PCR by:	Terrie Boguski, P.E. – Harmony Environmental tboguski@harmonyenviro.com

Limitations: Environmental declarations from different programs (ISO 14025) based upon different PCRs may not be comparable. Comparison of the environmental performance of Building Envelope Thermal Insulation using EPD information shall be based on the product's use and impacts at the building level, and therefore EPDs may not be used for comparability purposes when not considering the building energy use phase as instructed under this PCR. Full conformance with the PCR for Building Envelope Thermal Insulation allows EPD comparability only when all stages of a life cycle have been considered, when they comply with all referenced standards, use the same sub-category PCR, and use equivalent scenarios with respect to construction works. However, variations and deviations are possible. When comparing EPDs created using this PCR, variations and deviations are possible. Examples of variations include different LCA software and background LCI datasets that may lead to different results for upstream or downstream segments of the life cycle stages declared.

EPD SUMMARY

This declaration is an industry-average, Type III Environmental Product Declaration (EPD) by the Polyisocyanurate Insulation Manufacturers Association (PIMA) conducted in accordance with ISO 14025. The products presented in this EPD are representative for the product range for all PIMA member manufacturers identified in this study. The study covers 36 polyiso manufacturing facilities in the United States and Canada. Each facility's annual electricity use, natural gas use, water use and wastewater, polyiso packaging (shrink wrap), and solid waste data were divided by its annual production in board-feet (BF). Facility details such as location (to specify grid mix) and facility emissions handling were also included in the calculation. Finally, a production-weighted average across all manufacturing facilities was created to represent the industry average manufacturing of polyiso.

This document is based on the Life Cycle Assessment (LCA) study developed for PIMA by Long Trail Sustainability in accordance with industry accepted standards: Product Category Rules for Building-Related Products and Services Part A: Life Cycle Assessment Calculation Rules and Report Requirements (UL 10010, Version 3.2), and Product Category Rule (PCR) Guidance for Building-Related Products and Services Part B: Building Thermal Insulation EPD Requirements (UL10010-1, Version 2.0), ISO 14040, ISO 14044 and ISO 21930. This EPD provides users with information on environmental impacts of polyiso wall insulation products during their life cycle.

LIFE CYCLE ASSESSMENT SCOPE AND BOUNDARIES

System Boundary: Cradle-to-Grave.

This declaration is cradle-to-grave and the following life cycle stages are included as part of the system boundary: production, construction, use, and end-of-life. Each life cycle stage includes the following modules:

Production Stage

- **Supply of raw materials (A1):** Extraction, upstream processing and production of raw materials and energy associated with the production of polyiso wall insulation boards.
- **Transport of raw materials (A2):** Transport of materials (all chemical and material inputs including packaging) to polyiso wall insulation board manufacturing facilities.
- **Manufacturing of products (A3):** Production of polyiso wall insulation boards (including associated emissions from production facilities).

Construction Stage

- **Transport from gate to site (A4):** Transport of polyiso wall insulation boards in bundles from the manufacturing facilities to product distributor sites or directly to project job sites.
- **Assembly/Install (A5):** Installation of polyiso wall insulation boards including: unloading from the truck using a crane or all terrain forklift to a staging area on a job site, removal of all protective packaging, installation of individual wall insulation boards in a wall system by contracting crews, and removal and transport of installation waste scrap to a local landfill for disposal.

Use Stage

- **Use (B1):** There is no activity associated during the use of polyiso wall insulation boards.
- **Maintenance (B2):** Polyiso wall insulation boards are installed permanently within a weather protected exterior building envelope and no maintenance is required to retain the functional performance of the product.
- **Repair (B3):** When the weather protection components of the building envelope are designed and installed properly and adequately maintained, it is reasonable to expect that the polyiso wall insulation boards will not incur damage affecting its performance. Therefore, repair activity is not required.
- **Replacement (B4):** The building service life as defined in the PCR is 75 years, and as rationalized in the reference service life no replacement is required.
- **Refurbishment (B5):** Polyiso wall insulation boards require no refurbishment activity.
- **Operational Energy Use of Building Integrated System During Product Use (B6) and Operational Water Use of Building Integrated System During Product Use (B7):** Polyiso wall insulation boards alone are not integrated technical systems and have no declared activity in either of the modules.

End-of-Life Stage

- **Deconstruction (C1):** At the end-of-life, the polyiso wall insulation boards are removed when the building is decommissioned and transported to a landfill. Although, the insulation may be recovered from the wall system and reused, this activity is not considered in this study.
- **Transport (C2)**: Transport of polyiso wall insulation boards to a landfill.
- **Waste Processing (C3):** Polyiso wall insulation boards do not require waste processing.
- **Disposal (C4):** Disposal of polyiso wall insulation boards in a landfill.

Allocation Method: Mass allocation method was used to allocate input/output for sub-processes involving co-products. No allocation was necessary in the manufacturing of facers and polyiso foam that comprise wall insulation products because there are no co-products for these materials. The allocations are already applied to the secondary data (i.e., ecoinvent data) included in this study (ecoinvent center, 2019).

PRODUCT DESCRIPTION

Polyisocyanurate (polyiso) is a cellular closed-cell rigid foam plastic insulation. The polyiso wall insulation boards consist of a foam core sandwiched between two facers (top and bottom). The foam core is comprised of a thermoset polymer that hardens by curing from a viscous liquid prepolymer. The rigid foam is produced through the reaction of methylene diphenylene diisocyanate (MDI) with polyester polyol. Other additives such as catalyst, surfactant, flame retardant, and blowing agent (pentane or pentane blends) are part of the formulation. Pentane is a hydrocarbon with negligible ozone depletion potential (ODP) (U.S. EPA, 2018) and low global warming potential (GWP) (U.S. EPA, 2020). For nearly 20 years, the polyiso industry has only utilized pentane or pentane blends in product formulations. Upon mixing of the components, the viscous pre-polymer is laid between the facers, and a chemical reaction cross-links polymer chains creating a rigid and durable cellular structure. For wall applications, this study considers one type of facer, a glass reinforced aluminum foil facer (GRFF), which plays a critical role in accommodating a continuous manufacturing process.

Features and Benefits

The versatile, durable and sustainable polyiso wall insulation boards offer the following benefits:

- High thermal resistance
- Continuous thermal insulation and insulated sheathing
- Condensation control
- Air barrier
- Water resistive barrier
- Improved water management with a non-absorptive surface and closed-cell foam
- Lightweight and easy to install

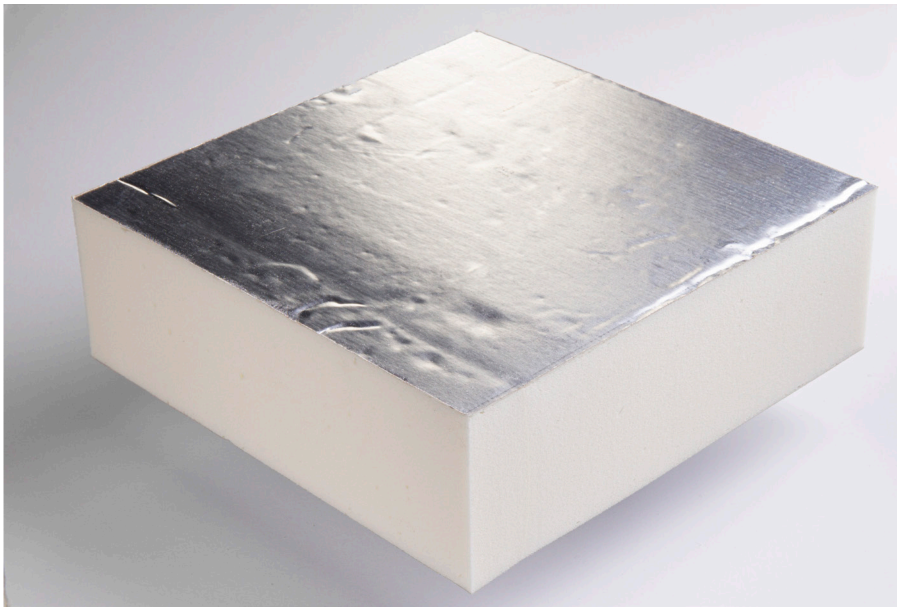

Image 1.
Polyiso Wall Insulation with Aluminum Foil Facer.

APPLICATION

Polyiso wall insulation boards may be used in residential, light commercial, commercial, and industrial projects on new buildings and retrofit applications under various cladding types as continuous insulation (see Figure 1):

- Exterior or interior in wood and metal stud-framed walls systems including direct-to-steel stud applications,
- Exterior or interior in masonry, masonry cavity systems or concrete wall systems,
- Attics and crawlspaces,
- Knee wall, vaulted and cathedral ceilings,
- Below grade and under slab, and
- Building enclosure energy retrofits over existing cladding (for increased energy efficiency and level surface for installation of new cladding).

Polyiso wall insulation boards are typically mechanically fastened to the back-up wall or the supporting structure. Polyiso is a versatile insulation, and it may be approved for other applications and functions (see Figure 1):

- Insulated sheathing,
- Water resistive barrier (WRB) (with all seams treated and installed in accordance with manufacturer's installation instructions),
- Air barrier (for use as a component of the air barrier system, with all seams taped or sealed and installed in accordance with manufacturer's installation instructions), and
- Vapor retarder.

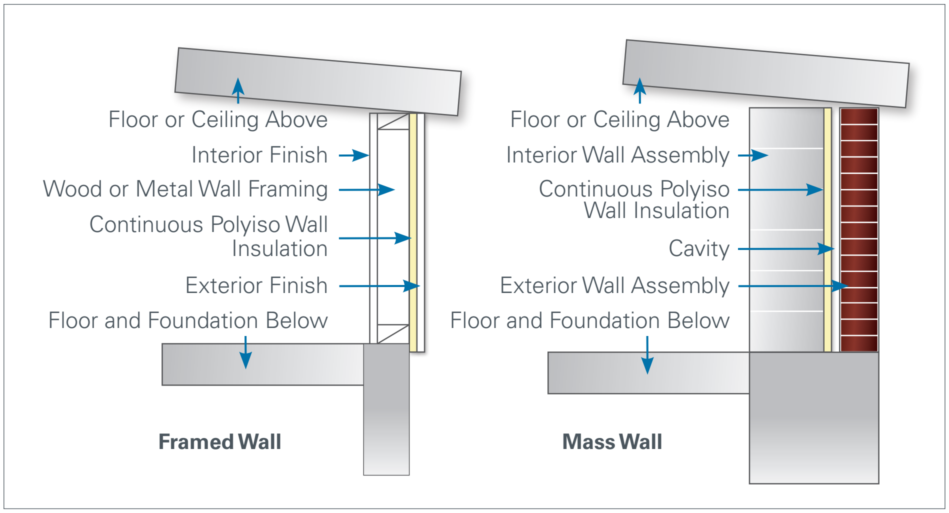

Figure 1.
Typical Assemblies with Polyiso Wall Insulation Boards Installed in Framed Wall (left image) and Mass Wall (right image).

TECHNICAL REQUIREMENTS

Polyiso wall insulation boards are manufactured to meet the requirements of industry consensus product specifications and standards in the United States and Canada. Note: Compliance with model building codes does not always ensure compliance with state or local building codes, which may be amended versions of these model codes. Always check with local building code officials to confirm compliance. Typical physical properties for polyiso wall insulation boards are listed in Table 1.

- ASTM C1289 – Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation.
- CAN/ULC-S704.1 – Standard for Thermal Insulation, Polyurethane and Polyisocyanurate, Boards, Faced.
- CSI and CSA MasterFormat® Reference: 072000 Thermal Protection, 072100 Thermal Insulation, 072500 Water-Resistive Barriers/Weather Barriers, 072700 Air Barriers.

Table 1.
Typical Physical Properties of Polyiso Wall Insulation Boards and Corresponding Requirements Listed in ASTM C1289 and CAN/ULC-S704.1 Standards.

PHYSICAL PROPERTY	STANDARD DESIGNATION	ASTM C1289 (TYPE I, CLASS 1 & 2)	CAN/ULC S704.1 (TYPE 1)
Thermal Resistance (R-value or long-term thermal resistance), °F·ft²·h/Btu (K·m²/W), min	→	6.0 (1.06) for 1.0-inch (25.4 mm) 9.9 (1.74) for 1.5-inch (25.4 mm) 12.0 (2.11) for 2.0-inch (25.4 mm) measured per ASTM C518 at 75°F (24°C) after 180 conditioning period	10.22 (1.80) for 1.97-inch (50-mm) thick board measured per CAN/ULC-S704.1, Annex D with reference to CAN/ULC-S770 Standard
Compressive Strength, psi (kPa), min	ASTM D1621	16 (110)	16 (110)
Flexural Strength, psi (kPa), min	ASTM C203	40 (275)	24.7 (170)
Tensile Strength, psf (kPa), min	→	500 (24) measured per ASTM C209	500 (24) measured per ASTM D1623
Dimensional Stability, % Linear Change, Thickness, Max	ASTM D2126	-40°F (-40°C) / ambient RH: 4.0 158°F (70°C) / 97% RH: 4.0 200°F (93°C) / ambient RH: 4.0	Not Applicable
Dimensional Stability, % Linear Change, Length and Width, max	ASTM D2126	Class 1 Class 2 -40°F (-40°C) / ambient RH: 2.0 1.5 158°F (70°C) / 97% RH: 2.0 1.5 200°F (93°C) / ambient RH: 4.0 1.5	-20°F (-29°C) / ambient RH: 2.0 158°F (70°C) / 97% RH: 2.0 176°F (80°C) / ambient RH: 2.0
Water Absorption, % by Volume, max	→	1.0 measured per ASTM C1763 – Procedure B	3.5 measured per ASTM D2842 – Procedure B
Water Vapor Permeance, perm (ng/Pa·s·m²)	ASTM E96/E96M Desiccant Method	Max 0.3 (17.2)	Class 1: ≤0.26 (≤15) Class 2: ≥0.26, ≤1.05 (≥15, ≤60) Class 3: > 1.05 (>60)

Thermal Performance: The use of continuous insulation is required in model building codes as a prescriptive measure of increasing energy efficiency of building envelope components including exterior walls. The thermal resistance (R-value or long-term thermal resistance, LTTR) is a measure of insulation's resistance to heat transfer for a given material thickness. The R-value of polyiso insulation wall board is determined on full thickness boards using a test method described in ASTM C518 "Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus." LTTR is determined using test methods described in CAN/ULC-S770 "Standard Test Method for Determination of Long-Term Thermal Resistance of Closed-Cell Thermal Insulating Foams," or ASTM C1303/1303M "Standard Test Method for Predicting Long-Term Thermal Resistance of Closed Cell Foam Insulation."

PROPERTIES OF DECLARED PRODUCT AS DELIVERED

The manufactured and cured polyiso wall insulation boards are typically shipped and delivered to jobsites stacked in bundles protected by a plastic wrap, plastic bag or both. The boards are typically 1.2 m by 2.4 m (4 feet by 8 feet) in size and stacked one on top of another to form a bundle. The number of polyiso boards in a bundle will vary depending on product thickness. Typically, the bundles are 1.2 m (48-inches) in height. For example, twice the number of 2.54 cm (1.0-inch-thick) boards can be stacked to make up the same height bundle compared to 2.0-inch-thick insulation boards. Typically, 48 boards at 2.54 cm (1.0-inch-thick), 24 boards at 5.08 cm (2.0-inch-thick) or 16 boards at 7.62 cm (3.0-inch-thick) comprise a bundle of polyiso wall insulation.

MATERIAL COMPOSITION

Polyiso wall insulation boards are comprised of a foam core and two facers on the top and bottom surfaces. The foam core consists of the average weighted formulation by mass listed in Table 2. More than half of the foam formulation consists of MDI which reacts with polyester polyol containing other chemicals including blowing agent, flame retardant, surfactant, catalyst and water. The chemical reaction forms a rigid cellular foam structure following a curing process. The glass reinforced aluminum foil facer (GRFF) is used in this study and it is comprised of an aluminum foil sheet reinforced with glass fiber scrim.

Table 2.
Weighted Average Foam Formulation Ranges
for Polyiso Wall Insulation Boards.

COMPONENT	FORMULATION RANGE (% by Mass)
MDI	61.5 – 61.8
Polyester Polyol	23.7 – 23.8
Blowing Agent (Pentane)	5.6 – 5.7
Flame Retardant (TCPP)	6.4
Surfactant	0.5 – 0.6
Catalyst	1.7-1.9
Water	0.2

(Note: Percentages may not total 100 due to rounding),

MANUFACTURING

This module includes manufacturing of polyiso wall insulation boards, packaging, manufacturing waste, and associated releases to the air, soil, ground, and surface water. The raw materials transported to the polyiso manufacturing plant consist of chemical liquids stored in onsite tanks or totes. The chemicals for the "A" side (MDI), the "B" side (polyester polyol plus catalysts, surfactants, and flame retardants) and the blowing agent (pentane) are pumped from storage into process tanks. The "B" side and blowing agent are then pumped to a mixer and then to a mix head where they are combined with the "A" side and injected between the top and bottom facers on the pour table. The mixed chemicals react rapidly to form a closed-cell foam board with a foam core sandwiched between the top and bottom facers. The rigid foam board moves through a heated laminator, which controls thickness and aids in cell formation, curing, and facer adhesion. The board exits the laminator and is fed through saws that trim the board to the desired width and then through a cross-cut saw that cuts the board to the desired lengths. The finished rigid boards are then stacked, packaged with plastic wrap, labeled, and moved via fork truck to a warehouse area for storage and eventual loading onto trucks for shipment. The manufacturing process for polyiso wall insulation boards at a typical manufacturing plant is illustrated in Figure 2. Bundles of polyiso wall insulation boards are wrapped and/or bagged in plastic prior to shipment from the manufacturing facility. Packaging used to wrap/shroud bundles is made from extruded low-density polyethylene (LDPE) film. Data was collected directly from each facility participating in this study on the wrap factor basis (pound of wrap per board foot). *(Note: Board foot is a unit of measure for the volume of material in the United States and Canada. It is the volume of: 1-foot (30.48 cm) length, 1-foot (30.48 cm) width and 1.0-inch (2.54 cm) thickness),*

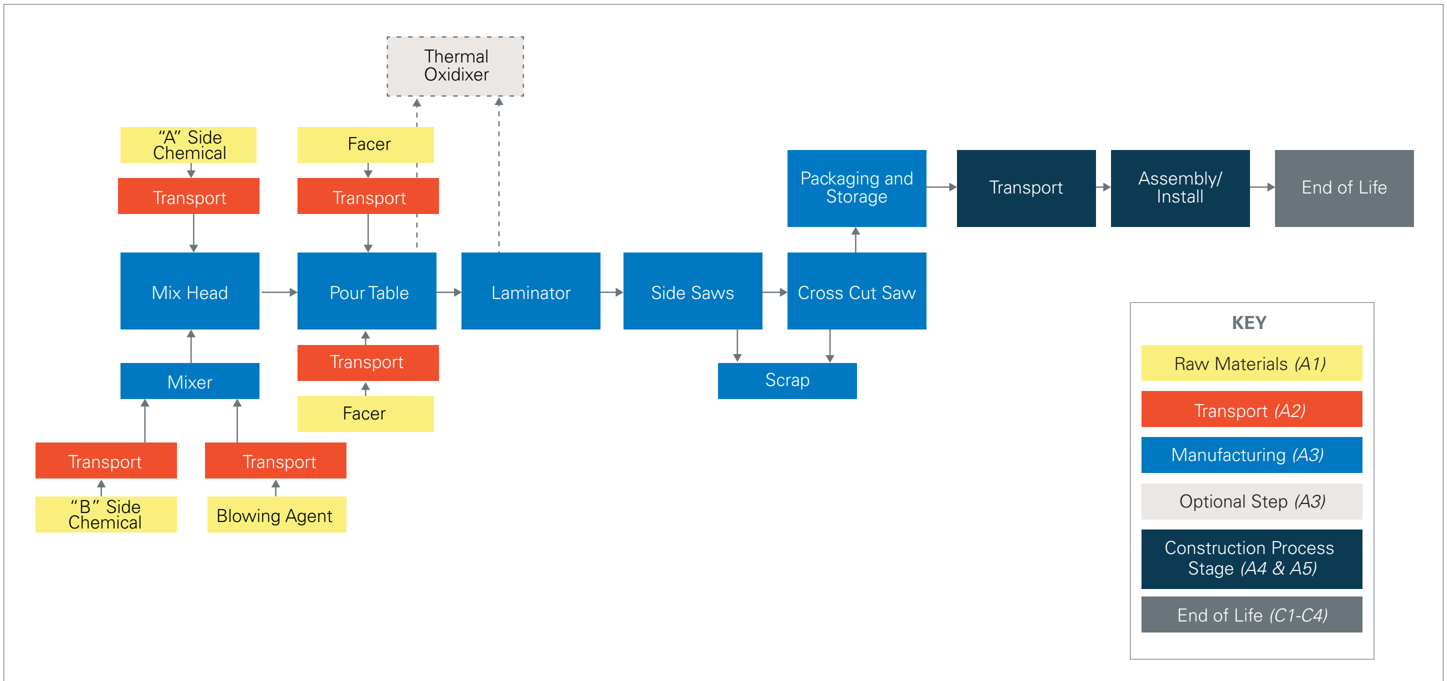

Figure 2.
Process Flow Diagram for Polyiso Wall Insulation.
(Note: Currently 44% of participating polyiso manufacturing facilities operate with thermal oxidizers for emissions control of pentane),

TRANSPORTATION

The polyiso wall insulation boards are transported in wrapped bundles from the manufacturing facilities to product distributor sites or directly to project job sites by a diesel-powered truck with a flatbed trailer. The average transport distance from production facility is 652 km (405 miles). Additional transportation details are reported in Table 3.

PRODUCT INSTALLATION

Upon delivery to the jobsite, the bundles of polyiso are unloaded from the truck using a crane or all terrain forklift and are staged on the ground, all packaging is removed, assumed to be landfilled, and the individual wall insulation boards are installed by contracting crews. The polyiso wall insulation boards are attached to the structure using mechanical fasteners or adhesives. The waste scrap from installation is collected, and transported to a local landfill for disposal. Disposal of installation waste scrap to a local landfill was modeled as 1% of the board foot. Additional installation details are reported in Table 4.

USE & REFERENCE SERVICE LIFE

The use phase follows the installation of polyiso wall insulation boards. In a wall system, continuous insulation is located between the supporting structure and the cladding or the interior finish. The cladding when installed properly and adequately maintained, protects the insulation from the environmental elements and weather during its use. Therefore, it is expected that polyiso wall insulation will not sustain damage that affects its performance and function, and does not require maintenance. As defined in the governing PCR, the Building Estimated Service Life (ESL) is 75 years. Polyiso wall insulation boards should serve their functional purpose for the life of the building, and do not require replacement during the building's ESL. Therefore, the declared RSL for wall products is established as equal to the PCR ESL for the building of 75 years, with no replacement required.

END OF LIFE

At the end of building service life, the polyiso wall insulation boards may be re-used, recovered and repurposed, or disposed. This study does not take re-use and recovery into account and it is assumed that the insulation is removed when the building is decommissioned and disposed of in a landfill. At the time of building deconstruction, insulation is removed manually or by cranes and transported 32 km (20 miles) to landfill sites by truck for disposal (Pavlovich, et. al., 2011). A United States specific dataset for landfilling plastic waste was used in the analysis.

CUT-OFF RULES

The cut-off criteria used for material and energy flows in this study ensures that all relevant environmental impacts are represented. In accordance with ISO 21930 Section 7.1.8 – "Criteria for the inclusion and exclusion of inputs and outputs", the cut-off rules applied in this study are described by the following [paraphrased]:

- All inputs and outputs to a (unit) process [are] included in the calculation…for which data is available.
- Data gaps [are] filled by worst-case estimates with proxy data [as is the case for catalysts]. [The] assumptions for such choices [are] documented.
- [All known material and energy flows are reported; no known flows are deliberately excluded.]
- Particular care [is] taken to include material and energy flows [known to contribute emissions into air, water or soil related to the environmental indicators of this standard]. [Conservative assumptions in combination with plausibility considerations and expert judgement can be used to demonstrate compliance with these criteria].

A 1% mass cut-off of the mass composition of the weighted average products were used to calculate renewable and non-renewable primary resources with energy content used as material inventory metrics. No known flows are deliberately excluded from this EPD.

DATA SOURCES

This study uses a combination of primary and secondary data. The primary data was collected from manufacturers and specific facilities for the production of polyester polyol, GRFF facer, and polyiso wall insulation boards. In instances when the primary data is not available, ecoinvent v3.5, Cut-off at Classification (ecoinvent centre, 2018), US LCI (NREL, 2015) and DATASMART v2018.1 (Long Trail Sustainability, 2018), which contain detailed peer reviewed LCI data are used.

DATA QUALITY

The quality of the data is representative of the processes modeled as the primary data comes from day-to-day production of polyiso wall insulation boards. Additional information regarding time, geographic and technology coverage is provided below:

TIME COVERAGE: Primary data for production of polyester polyol and polyiso wall insulation boards (including energy, water and raw material inputs, transportation distances and modes for raw materials, direct emissions, wastewater and manufacturing scrap), was collected in 2018 for the reference year 2017, with the exception of GRFF facer which was collected in 2019 for the 2019 reference year.

GEOGRAPHIC COVERAGE: The geographic coverage of this study includes manufacturing, distribution and installation of polyiso wall insulation boards in the United States and Canada.

TECHNOLOGY COVERAGE: The process technology modeled is based on polyiso foam manufacturers, polyester polyol manufacturers, and facer manufacturers representing production in the United States and Canada. Primary data was collected for the production of polyester polyols, GRFF facers, and manufacturing of polyiso wall insulation boards (including energy, water and raw material inputs, transportation distances and modes for raw materials, direct emissions, wastewater and manufacturing waste).

PERIOD UNDER REVIEW

The primary data collected and used in this study represents the manufacture of polyester polyols, and Polyiso wall insulation boards during the 2017 calendar year, and the production of GRFF facers from January through June of 2019.

ESTIMATES AND ASSUMPTIONS

The material and energy input for the production of polyiso wall Insulation boards were modeled with data collected from 36 manufacturing facilities in the Unites States and Canada. MDI was used to model catalyst impacts and is a worst-case estimate. The amount of MDI used to approximate each catalyst is doubled; 1kg of catalyst is modeled with 2 kg of MDI as a proxy. The disposal of installation waste scrap sent to the landfill was assumed to be 1% of board foot. The impacts associated with installing and removing boards on building wall were estimated using data collected from a previous LCA project, as the installation methods have not changed (Pavlovich, et al., 2011), and are described in greater detail in the LCA report. At the end of service life, the transport distance to the landfill for disposed insulation is estimated at 32 km (20 miles).

LCA SCENARIOS AND ADDITIONAL TECHNICAL INFORMATION

The following technical information was considered in the life cycle assessment.

Table 3.
Transport to building site details (A4).

NAME	VALUE	UNIT
Fuel Type	Diesel	
Vehicle Type	Unspecified freight lorry	
Transport distance*	652	Km
Weight of products transported	Dependent on product	
Volume of products transported	Dependent on product	
*Data on average transportation distance to building site was collected from each polyiso manufacturing facility. NOTE: Liters of fuel, capacity utilization, gross density of products transported and capacity utilization volume factor determined by the ecoinvent transportation process used: *Transport, freight, lorry, unspecified.*		

Table 4.
Installation into the Building (A5).

NAME	VALUE	UNIT
Diesel for construction equipment	2.36E-04	Gallons diesel/ft^2
VOC content	N/A	ɥg/m3
Production loss per functional unit	1	%
Waste materials at the construction site before waste processing, generated by product installation (assumed landfilled)	0.0108	kg
Output materials resulting from on-site waste processing, generated by packaging waste (assumed landfilled)	0.0035	kg
Note	The data for VOC content is not available and it is designated with a symbol N/A.	

Table 5.
Reference Service Life.

NAME	VALUE	UNIT
RSL	75	years
Declared product properties (at the gate) and finishes, etc.	1	m^2
	1	R_{SI}

Table 6.
Disposal/End of life (C1-C4).

NAME	VALUE	UNIT
Landfill	100	%

LCA RESULTS

Functional Unit: The functional unit for building envelope thermal insulation as defined by the PCR (Part B, Section 3.1) is: 1 m^2 of installed insulation with a thickness providing a thermal resistance of 1 m^2·K/W and with a building service life of 75 years (packaging included). In the United States, thermal resistance (R_{IP}) is commonly reported in imperial system unit of measure (ft^2·°F·h/Btu) with 1 m^2·K/W equivalent to (5.678 ft^2·°F·h/Btu). The R-value of polyiso wall insulation boards increases slightly on a per inch basis with increasing product thickness. Similarly, the influence of the facers on the polyiso impact profile decreases with increasing product thickness. Therefore, a commonly specified intermediate thickness of product is selected for the functional unit to represent the LCA results. The data for a 0.051 m (2-inch) thick, GRFF faced polyiso wall insulation boards with 2.3 m^2·K/W (13.1 ft^2·°F·h/Btu) R-value is normalized to a thermal resistance of 1 m^2·K/W (5.678 ft^2·°F·h/Btu). Table 7 provides the characteristics of the functional unit.

Table 7.
Functional Unit Properties.

NAME	VALUE	UNIT
Functional Unit	1 m^2 (10.76 ft^2) of installed insulation with a thickness providing a thermal resistance of 1 m^2·K/W (5.678 ft2·°F·h/Btu)	
Mass	1.08 (2.38)	kg (lb)
Thickness to achieve functional unit	0.022 (0.866)	m (in)

This declaration is cradle-to-grave and all information modules are declared. As discussed in the Life Cycle Assessment Scope and Boundaries Section, Modules B1, B2, B3, B4, B5, B6, B7, C1 and C3 do not contribute to impact and are declared as zero. Optional Module D – Benefits and Loads Beyond the System Boundary – is not included in this LCA study. In the interest of conciseness, the tables with results in this section do not include these modules.

Table 8.
Description of the System Boundary Modules.

PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE					END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	D
Raw Material Supply	Transport	Manufacturing	Transport from Gate to Site	Assembly / Install	Use	Maintenance	Repair	Replacement	Refurbishment	Deconstruction	Transport	Waste Processing	Disposal	Reuse, Recovery, Recycling Potential
					B6	Building Operational Energy Use During Product Use			X					
					B7	Building Operational Water Use During Product Use			X					
X	X	X	X	X	X	X	X	X	X	X	X	X	X	MND
MND = module not declared														

The following tables detail the results of the wall products by functional unit R_{SI}=1 $m^2 \cdot K/W$, including the impact assessment results using the TRACI 2.1 impact assessment method and the inventory metrics required by the PCR. These six impact categories are globally deemed mature enough to be included in Type III environmental declarations. Other categories are being developed and defined, and the LCA practice should continue making advances in their development. However, the EPD users shall not use additional measures for comparative purposes. LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

Table 9.
TRACI 2.1 Impact Categories – Functional Unit for all Life Cycle Stages Totals.

IMPACT CATEGORY	UNIT	TOTAL VALUE
GWP: Global Warming Potential	kg CO_2 eq	4.29E+00
ODP: Ozone Depletion Potential	kg CFC-11 eq	2.41E-07
AP: Acidification Potential	kg SO_2 eq	2.28E-02
EP: Eutrophication Potential	kg N eq	2.20E-02
POCP: Photochemical Oxidant Creation Potential	kg O_3 eq	2.66E-01
ADP_{fossil}: Abiotic Resource Depletion Potential of Non-renewable energy resources	MJ, LHV	7.96E+00

Table 10.
TRACI 2.1 Impact Categories – Functional Unit by System Boundary Module.

IMPACT CATEGORY	UNIT	A1	A2	A3	A4	A5	C2	C4
GWP	kg CO_2 eq	3.86E+00	6.99E-02	1.66E-01	6.93E-02	2.69E-02	3.89E-03	9.51E-02
ODP	kg CFC-11 eq	1.93E-07	1.49E-08	1.26E-08	1.72E-08	5.12E-11	9.68E-10	1.71E-09
AP	kg SO_2 eq	2.10E-02	6.32E-04	2.79E-04	3.56E-04	3.55E-04	2.00E-05	1.13E-04
EP	kg N eq	7.33E-03	1.25E-04	7.16E-04	8.31E-05	2.75E-05	4.66E-06	1.37E-02
POCP	kg O_3 eq	2.20E-01	1.70E-02	5.29E-03	8.95E-03	1.15E-02	5.02E-04	2.77E-03
ADP_{fossil}	MJ, LHV	7.43E+00	1.35E-01	1.51E-01	1.55E-01	5.45E-02	8.71E-03	2.47E-02

Table 11.
Resource Use Indicators – Functional Unit by System Boundary Module.

RESOURCE INDICATOR	UNIT	A1	A2	A3	A4	A5	C2	C4
RPRE	MJ, LHV	3.20E+00	2.03E-02	7.49E-02	1.12E-02	8.32E-04	6.27E-04	4.58E-03
RPRM	MJ, LHV	3.01E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRPRE	MJ, LHV	4.53E+01	1.00E+00	1.71E+00	1.09E+00	3.69E-01	6.10E-02	1.99E-01
NRPRM	MJ, LHV	2.06E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SM	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m^3	2.98E-02	2.16E-04	4.90E-04	1.83E-04	3.35E-05	1.03E-05	2.40E-04
RSF	MJ	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NRSF	MJ	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RE	MJ	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Abbreviations	RPRE: Renewable primary resources used as an energy carrier (fuel); RPRM: Renewable primary resources with energy content used as material; NRPRE: Non-renewable primary resources used as an energy carrier (fuel); NRPRM: Non-renewable primary resources used as material; SM: Secondary Materials; FW: Use of net fresh water resources; RSF: Renewable secondary fuels; NRSF: Non-renewable secondary fuels; RE: Recovered energy.							
Note	The data for following resource indicators; RSF: Renewable secondary fuels; NRSF: Non-renewable secondary fuels; RE: Recovered energy, is not available and it is designated with a symbol N/A.							

Table 12.
Waste and Other Outputs – Functional Unit by System Boundary Module.

OUTPUT FLOWS	UNIT	A1	A2	A3	A4	A5	C2	C4
HWD	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.25E-06
NHWD	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.07E-02
MR	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.80E-05
HLRW	kg	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ILLRW	kg	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CRU	kg	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MER	kg	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EE	MJ	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Abbreviations	HWD: Hazardous waste disposed; NHWD: Non-hazardous waste disposed: MR: Materials for Recycle; HLRW: High level radioactive waste disposed; ILLRW: Intermediate- and low-level radioactive waste, conditioned, to final repository; CRU: Components for re-use; MER: Materials for energy recovery; EE: Exported energy.							
Note	No substances required to be reported as hazardous are associated with the production of this product, however a small percentage of the manufacturing waste is disposed of as hazardous waste. The data the following output flows; for HLRW: High level radioactive waste disposed; ILLRW: Intermediate- and low-level radioactive waste, conditioned, to final repository; CRU: Components for re-use; MER: Materials for energy recovery; EE: Exported energy, is not available and it is designated with symbol N/A.							

LCA INTERPRETATION

Module Impact Analysis

The life cycle assessment results inform the users on the cradle-to-grave environmental profile for polyiso wall insulation boards. As described in the Use and Reference Service Life section of this declaration, all life cycle stages environmental impacts for polyiso are connected with the original building construction with the ESL of 75 years. Polyiso wall insulation boards should serve their functional purpose for the life of the building, and do not require replacement during the building's ESL. Therefore, the declared RSL for polyiso wall insulation boards is established as equal to the PCR Estimated Service Life (ESL) for the building of 75 years with no replacement required. The environmental profile for polyiso wall insulation boards is captured in modules A1 through A5, C2 and C4. When assessing the environmental profiles of products, Global Warming Potential (GWP) is an important Impact category. The relative impact of modules on GWP for polyiso wall insulation boards with GRFF facers is illustrated in Figure 3. Module A1 (raw materials) is the most dominant module accounting for 90.0% of the impacts. Module A3 (manufacturing of polyiso) contributes 3.9%. Module C4 (disposal) contributes 2.2% to the GWP impact. The remaining modules A2, A4, A5, C2, each contribute less than 2.0%.

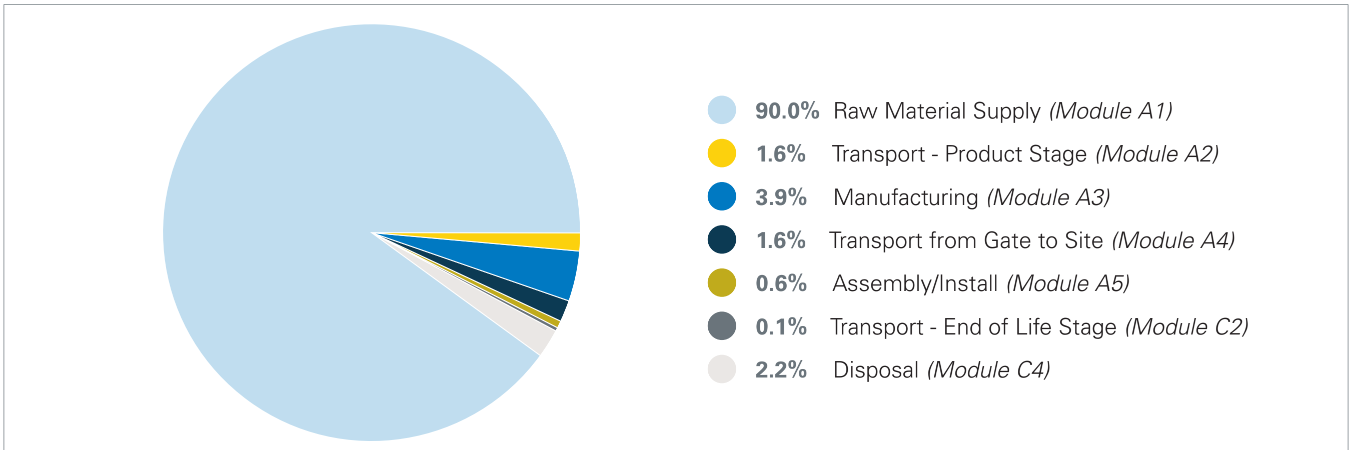

Figure 3.
Relative Impact of Modules in Global Warming Potential for GRFF faced Polyiso Wall Insulation Boards.

The analysis in Table 13 indicates that Module A1 (raw materials) dominates the environmental profile of polyiso wall Insulation boards. The aggregated primary and secondary data indicate that extraction and processing of raw materials has the largest impact. The polyiso industry is characterized as having a large number of plants that produce polyiso wall Insulation boards located throughout the Unites States and Canada. Many plants are located near large population centers with significant construction activity, thus reducing the impacts from transportation.

Environmental Profiles for Common Polyiso Thicknesses

Polyiso wall insulation boards are available in incremental R_{IP}-values from 6 ft2·°F·h/Btu to 25 ft2·°F·h/Btu. For this declaration, cradle–to-grave environmental profiles were calculated on three popular thicknesses: 1.0-inch (R_{IP} – 6.5 ft2·°F·h/Btu), 2.0-inches (R_{IP} – 13.1 ft2·°F·h/Btu), and 3.0-inches (R_{IP} – 19.7 ft2·°F·h/Btu). To provide the users of this document the opportunity to assess common polyiso wall insulation configurations, the Impact and Indicator metrics are listed for all life cycle stages for each of these three thicknesses corresponding to the minimum R-value requirements of the IECC and ASHRAE 90.1 Standard for continuous insulation installed on the exterior walls in all climate zones throughout the United States and Canada. These results are provided in Table 13. **Impact and Indicator values on any thickness of product between 1.0 and 3.0-inches can be calculated through linear extrapolation from the data in this Table.**

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Table 13.
Impacts/Indicators for All Life Cycle Stages of Common Wall Product Thicknesses.

IMPACT CATEGORY / ENVIRONMENTAL INDICATOR		UNIT	1.0-inch Thick RIP: 6.5		2.0-inch Thick RIP: 13.1		3.0-inch Thick RIP: 19.7	
			Per 1 ft^2	Per 1 m^2	Per 1 ft^2	Per 1 m^2	Per 1 ft^2	Per 1 m^2
TRACI 2.1 IMPACT CATEGORIES	**GWP: Global Warming Potential**	kg CO_2 eq	6.79E-01	7.30E+00	9.20E-01	9.90E+00	1.17E+00	1.26E+01
	ODP: Ozone Depletion Potential	kg CFC-11 eq	3.51E-08	3.78E-07	5.16E-08	5.55E-07	6.92E-08	7.45E-07
	AP: Acidification Potential	kg SO_2 eq	3.68E-03	3.96E-02	4.88E-03	5.25E-02	6.15E-03	6.62E-02
	EP: Eutrophication Potential	kg N eq	3.18E-03	3.42E-02	4.71E-03	5.07E-02	6.31E-03	6.79E-02
	POCP: Photochemical Oxidant Creation Potential	kg O_3 eq	4.45E-02	4.79E-01	5.71E-02	6.15E-01	7.06E-02	7.59E-01
	ADP_{fossil}: Abiotic Resource Depletion Potential of Non-Renewable Energy Resources	MJ, LHV	1.01E+00	1.09E+01	1.71E+00	1.84E+01	2.44E+00	2.62E+01
RESOURCE USE INDICATORS	**RPR_E: Renewable Primary Resources Used as an Energy Carrier (Fuel)**	MJ, LHV	5.95E-01	6.40E+00	7.10E-01	7.64E+00	0.00E+00	0.00E+00
	RPR_M: Renewable Primary Resources with Energy Content Used as Material	MJ, LHV	3.32E-02	3.57E-01	6.44E-02	6.94E-01	0.00E+00	0.00E+00
	$NRPR_E$: Non-Renewable Primary Resources Used as an Energy Carrier (Fuel)	MJ, LHV	7.60E+00	8.18E+01	1.07E+01	1.15E+02	0.00E+00	0.00E+00
	$NRPR_M$: Non-Renewable Primary Resources Used as Material	MJ, LHV	2.24E+00	2.42E+01	4.41E+00	4.75E+01	0.00E+00	0.00E+00
	PED: Total Primary Energy Demand	MJ, LHV	1.05E+01	1.13E+02	1.58E+01	1.71E+02	2.15E+01	2.31E+02
	SM: Secondary Materials	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	FW: Use of Net Fresh Water Resources	m^3	5.57E-03	5.99E-02	0.00E+00	0.00E+00	7.76E-03	8.35E-02
WASTE OUTPUT	**HWD: Hazardous Waste Disposed**	kg	4.58E-07	4.93E-06	9.11E-07	9.80E-06	1.38E-06	1.48E-05
	NHWD: Non-Hazardous Waste Disposed	kg	1.14E-03	1.23E-02	2.29E-03	2.46E-02	3.47E-03	3.73E-02
	MR: Materials for Recycle	kg	1.93E-05	2.08E-04	1.67E-05	1.80E-04	2.54E-05	2.73E-04

ADDITIONAL ENVIRONMENTAL INFORMATION

Air and Water Resistive Barrier: The use of polyiso wall insulation boards as a component of an air barrier assembly reduces air infiltration and exfiltration across the building enclosure, and improves the energy efficiency of exterior wall assemblies. Polyiso wall insulation may be considered as a component of an air barrier system when tested and installed in accordance with the relevant section(s) of the building codes and the manufacturer's installation instructions. Model building codes list polyiso insulation as an air barrier material when installed at a minimum 0.5-inch (0.013 m) thickness. Polyiso wall insulation boards with the impermeable foil facer may also serve as a water resistive barrier when tested and installed in accordance with the relevant section of the building codes and manufacturer's installation instructions.

Fire Performance: The fire performance of foam plastic insulation products such as polyiso wall insulation boards is evaluated using both material and system (assembly) tests in accordance with the requirements of International Building Code in United States and National Building Code of Canada. At a material level, important fire characteristics include: flame spread index (FSI) and smoke developed index (SDI) conducted in accordance with ASTM E84 "Standard Test Method for Surface Burning Characteristics of Building Materials" or equivalent standards such as UL 723 and NFPA 255. In Canada, the corresponding standard to ASTM E84 is CAN/ULC-S102 "Standard Method of Test for Surface Burning Characteristics of Building Materials and Assemblies." This declaration is based on polyiso wall insulation boards that are designated as Class A with FSI ≤25 and SDI <450.

The fire performance of exterior wall assemblies is an important consideration and must be balanced with energy efficiency goals. With respect to wall assemblies in Type I through IV construction in the United States, NFPA 285 "Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Wall Assemblies Containing Combustible Components" is a critical component in the design of code compliant, high-performance building envelopes that incorporate foam plastic insulation products such as polyiso wall insulation boards. Developed by the National Fire Protection Association, NFPA 285 is a fire test standard that measures the flame propagation characteristics of exterior wall assemblies, and it provides a standardized fire test procedure for evaluating the suitability of exterior wall assemblies constructed using combustible materials or components for installation on buildings where the exterior walls are required to be non-combustible. Manufacturers of polyiso wall insulation boards have conducted extensive NFPA 285 testing for applications with various wall assemblies and cladding types. Similar evaluations are performed in Canada using the test method CAN/ULC-S134 "Standard Method of Fire Test of Exterior Wall Assemblies." Additional fire evaluation requirements for foam plastic insulations and the use of foam plastics in specific wall applications are contained in the building codes of the United States and Canada.

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3. ASTM C209 – Standard Test Method for Cellulosic Fiber Insulating Board.
4. ASTM C518 – Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus.
5. ASTM C1289 – Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board.
6. ASTM C1303/C1303M – Test Method for Predicting Long-Term Thermal Resistance of Closed-Cell Foam Insulation.
7. ASTM C1763 – Test Method for Water Absorption by Immersion of Thermal Insulation Materials.
8. ASTM D1621 – Test Method for Compressive Properties of Rigid Cellular Plastics.
9. ASTM D1623 – Standard Test Method for Tensile and Tensile Adhesion Properties of Rigid Cellular Plastics.
10. ASTM D2126 – Test Method for Response of Rigid Cellular Plastics to Thermal and Humid Aging.
11. ASTM D2842 – Standard Test Method for Water Absorption of Rigid Cellular Plastics.
12. ASTM E96/E96M – Test Method for Water Vapor Transmission of Materials.
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14. CAN/ULC-S134 – Standard Method of Fire Test of Exterior Wall Assemblies.
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