Polyiso Roof Insulation Boards

JOHNS MANVILLE

ENVIRONMENTAL PRODUCT DECLARATION

ISO 14025:2006 and ISO 21930:2017

NSF Certified Environmental Product Declaration www.nsf.org

Johns Manville is pleased to present this Environmental Product Declaration (EPD) for Polyiso Roof Insulation Boards. This EPD was developed in compliance with ISO 14025 and ISO 21930 and has been verified by NSF.

The LCA and the EPD were prepared by Vertima Inc. The EPD includes cradle-to-grave life cycle assessment (LCA) results.

For more information about Johns Manville, visit www.jm.com.

For any explanatory material regarding this EPD, please contact the program operator.

1. GENERAL INFORMATION

PCR GENERAL INFORMATION			
Reference PCR	PCR Part B: Building Envelope Thermal Insulation EPD Requirements (UL 10010-1), v.4.0 and its core PCR Part A: Life Cycle Assessment Calculation Rules and Report Requirements (UL 10010), v.4.0 UL Environment November 2025 to November 2030 (validity period of PCR Part B) March 28, 2022 to March 28, 2027 (validity period of PCR Part A)		
The PCR review was conducted by:	*Thomas Gloria, PhD (chair) Industrial Ecology Consultants t.gloria@ industrial-ecology.com*	*Cara Vought Sustainable Solutions cara@ sustainablesolutions. com*	*Andre Desjarlais Oak Ridge National Laboratory desjarlaisa@ornl.gov*

EPD GENERAL INFORMATION		
Program Operator	NSF 789 N. Dixboro Road Ann Arbor, Michigan 48105 USA www.nsf.org	
General Program Instructions	NSF International, NSF Certification Policies for Environmental Product Declarations (EPD), 2022	
Declared Products	**ENRGY 3** **ENRGY 3 CGF**	
EPD Registration Number EPD11224	**EPD Date of Issue** April 28, 2026	**EPD Period of Validity** April 28, 2026 to April 28, 2031
EPD Recipient Organization	Johns Manville 717 17th Street Denver, CO 80202 USA	

EPD Type/Scope and Functional Unit Manufacturer-average, product-average cradle-to-grave EPD with functional unit of 1 m² of insulation material with a thickness that gives an average thermal resistance of	**Year of Reported Manufacturer Primary Data** 2023

Geographical Scope	**LCA Software**	**LCI Databases**	**LCIA Methodology**
North America	OpenLCA v.2.03	Ecoinvent 3.9.1	TRACI 2.2, IPCC AR5, CML 4.8

This LCA and EPD were prepared by:	Vertima Inc. www.vertima.ca
This EPD and LCA were independently verified in accordance with ISO 14025:2006, ISO 14040:2006, ISO 14044:2006 and ISO 21930:2107, as well as the UL Environment PCR "Part B: Building Envelope Thermal Insulation EPD Requirements (UL 10010-1) v.4.0," and PCR "Part A: Life Cycle Assessment Calculation Rules and Report Requirements (UL 10010), v.4.0," which serves as the core PCR. ☐ Internal ☒ External	Jack Geibig Ecoform, LLC

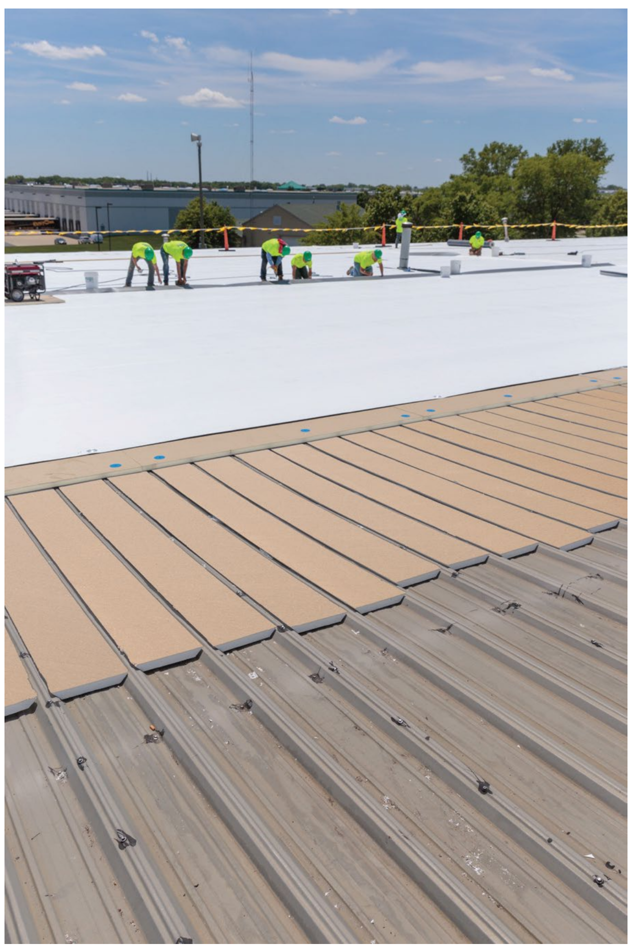
The owner of the declaration shall be liable for the underlying information and evidence; NSF or its affiliates, shall not be liable with respect to manufacturer information, life cycle assessment data, and evidence.

LIMITATIONS

Environmental declarations within the same product category but from different programs may not be comparable. [1]

Comparison of the environmental performance of products 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 products or roof cover protection boards 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 Part B PCR, and use equivalent scenarios with respect to construction works. However, variations and deviations are possible (e.g. Different LCA software and background LCI datasets that may lead to differences in calculated and reported results for upstream or downstream of the life cycle stages declared).[2], [3]

The results of this study are representative of Johns Manville 2023 production. Furthermore, they are for roof insulation boards with specific facer types. The results are manufacturer-averaged; hence, the A1-C4 result includes variation ranging from 4%-13% depending on the impact category.



[Photo courtesy of Johns Manville]

2. PRODUCT SYSTEM DESCRIPTION

Johns Manville (JM) is a global manufacturer of premium-quality building products for insulation, roofing, fibers and nonwovens for commercial, industrial and residential applications.

We ensure that each of our products not only performs, but also contributes to the health, safety, and sustainability of the environments where they are used.

We strive to ensure that our products meet the rigorous demands of their applications while focusing on finding new ways to reduce our environmental footprint, and we want to provide you with reliable materials that will allow you to do the same.

The use of JM's products improves energy efficiency in homes and buildings as the quickest and most cost-effective way to reduce energy use and lower greenhouse gas emissions.

2.1. PRODUCT DESCRIPTION

Johns Manville's ENRGY 3® roof product lines[1] are closed-cell polyisocyanurate foam core with either an inorganic-coated glass facer (CGF) on each side or a glass-fiber reinforced cellulosic facer (GRF) on each side, respectively called ENRGY 3® CGF and ENRGY3®. 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 diphenyl 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) [7] and low global warming potential (GWP).[8] For nearly 20 years, the polyiso industry has only utilized pentane or pentane blends in product formulations. Typical roof insulation board have a compressive strength of 20 psi or 25 psi.

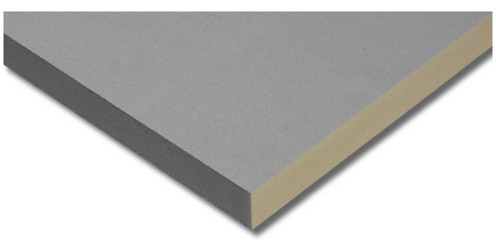


Figure 1: ENRGY 3® CGF (left) and ENRGY 3® (right) polyiso roof insulation board.

[1] CSI and CSA MasterFormat® Reference: 07 22 16 Roof board insulation.

2.2. PRODUCT APPLICATION

Polyiso roof insulation boards may be used in residential, light commercial, commercial, and industrial roof construction projects on new buildings and on existing buildings during reroofing. Polyiso is the most widely used type of insulation in above-deck commercial roof applications in the United States and Canada. In commercial roof systems, one or more layers of polyiso are installed (with board joints staggered) direct-to-deck (i.e., steel, concrete, or wood) and below the membrane to provide continuous insulation. On low-slope roof applications, polyiso can be installed as a flat stock or as a tapered product to provide improved slope and more effectively manage rainwater drainage. Polyiso may be attached to the roof deck using mechanical fasteners or adhesives to achieve the desired system performance. Polyiso is a versatile insulation, and it is compatible with all low-slope roof covering types including single-ply membrane systems (i.e., TPO, PVC and EPDM), modified bitumen systems, built-up roofing, standing-seam metal roofing, and metal panels. The roof systems may be mechanically attached through the polyiso insulation, adhered to the polyiso facer or held in place with ballast. A typical roof system with a metal deck is illustrated in Figure 2. Many factors and design considerations impact the selection of a roof system, and additional components such as an air barrier, vapor retarder, thermal barrier, and cover board may be required in specific applications. Polyiso insulation may be installed in direct-to-deck applications without a thermal or ignition barrier. On steep-slope roof applications, polyiso can be used as a part of vented nail base system below asphalt, composite, and metal shingles and metal panels.

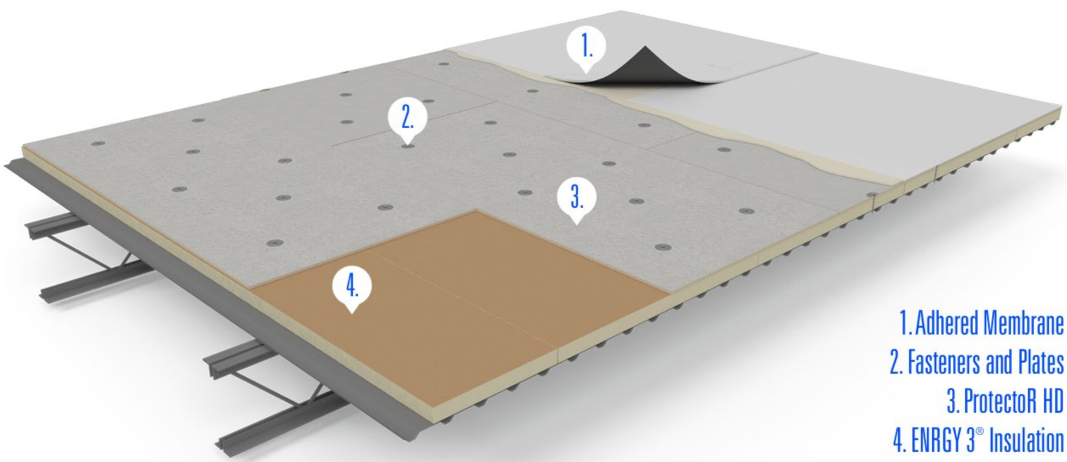


Figure 2: Typical roof assembly with ENRGY 3® roof insulation boards installed direct-to-steel deck.

2.3. MATERIAL COMPOSITION

Polyiso roof 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 1. 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 product contains no other additives, nor ancillary materials known to remain in the product. The chemical reaction forms a rigid cellular foam structure following a curing process.

The two most common types of facers in polyiso roof insulation and used in this study are: (1) glass fiber reinforced cellulosic facer (GRF) and (2) coated polymer-bonded glass fiber (CGF). The GRF is comprised of a cellulosic fiber felt containing glass fiber for added strength. The CGF facer is composed of a non-woven glass fiber mat bonded with organic polymer binder and coated with polymer coatings.

Table 1: Weighted average polyiso roof insulation board material composition and foam formulation ranges.

Component		Formulation Range (% by mass) Facer: CGF	Formulation Range (% by mass) Facer: GRF
Facer		59.6%	36.6%
Foam		40.4%	63.4%
Foam composition	MDI	58.5% - 59.2%	58.5% - 59.1%
	Polyester Polyol	27.5% - 28.8%	27.7% - 28.9%
	Blowing Agent (Pentane)	5.2% - 7.0%	5.3% - 7.1%
	Flame Retardant (TCPP)	4.2% - 4.3%	4.2% - 4.3%
	Surfactant	0.4% - 0.5%	0.4% - 0.5%
	Catalyst	2.0% - 2.3%	1.9% - 2.2%
	Water	0.1%	0.1%

2.4. TECHNICAL DATA

Polyiso roof 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 roof insulation boards are listed in Table 2.

- ASTM C1289 – Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation.
- CAN/ULC-704.1 – Standard for Thermal Insulation, Polyurethane and Polyisocyanurate, Boards, Faced.

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 roof. 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 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."

Table 2: Typical physical properties of polyiso roof insulation boards and corresponding requirements listed in ASTM C1289 and CAN/ULC-704.1 standards.

Physical Property	Standard Designation	ASTM C1289 (Type II, Class 1 and 2)	CAN/ULC-704.1 (Type 1, 2 and 3)
Thermal Resistance, Min		Type II, Class 1 25.4mm (1.0-inch): RSI 0.97 m^2 K/W (R-value 5.6 ft^2 °F h/Btu) 38.1mm (1.5-inch): RSI 1.48 m^2 K/W (R-value 8.4 ft^2 °F h/Btu) 50.8mm (2.0-inch RSI 1.97 m^2 K/W (R-value 11.2 ft^2 °F h/Btu) Type II, Class 2 25.4mm (1.0-inch): RSI 0.93 m^2 K/W (R-value 5.3 ft^2 °F h/Btu) 38.1mm (1.5-inch): RSI 1.41 m^2 K/W (R-value 8.0 ft^2 °F h/Btu) 50.8mm (2.0-inch RSI 1.87 m^2 K/W (R-value 10.6 ft^2 °F h/Btu) Long-term thermal resistance determined per ASTM C518 after 180-day conditioning	50.0mm (1.97-inch): RSI 1.80 m^2 K/W (R-value 10.22 ft^2 °F h/Btu) Long-term thermal resistance determined per CAN/ULC-S770
Compressive Strength, Min	ASTM D1621	Grade 2: 20 psi (140 kPa) Grade 3: 25 psi (170 kPa)	Type 2: 20 psi (140 kPa) Type 3: 25 psi (170 kPa)
Flexural Strength, Min	ASTM C203	40 psi (275 kPa)	Type 2: 35.0 psi (275.0 kPa) Type 3: 35.0 psi (275.0 kPa)
Tensile Strength, Min		500 psf (24 kPa) determined per ASTM C209	Type 2: 731 psf (35.0 kPa) Type 3: 731 psf (35.0 kPa) determined 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 2.0. 158°F (70°C) / 97% RH: 2.0 2.0 200°F (93°C) / ambient RH: 2.0 2.0	-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		1.5 determined per ASTM C1763 – Procedure B	3.5 determined per ASTM D2842 – Procedure B
Water Vapor Permeance	ASTM E96/E96M Desiccant Method	Class 1: ≤1.5 perm (≤85.8 ng/Pa·s·m^2) Class 2: ≤4.0 perm (≤228.8 ng/Pa·s·m^2)	Class 1: ≤0.26 perm (≤15 ng/Pa·s·m^2) Class 2: >0.26, ≤1.57 perm (>15, ≤90 ng/Pa·s·m^2) Class 3: > 1.57 perm (>90 ng/Pa·s·m^2)

2.5. MANUFACTURING

An overview of the manufacturing process for polyiso insulation is illustrated in Figure 3 *and* is *described below.*

Manufacturing Process Detail:

- *Raw Material Unloading and Storage - Raw materials are delivered to the manufacturing plant via bulk shipment methods including rail cars or large totes. After unloading, certain materials are transferred and stored on-site in large tanks or totes.*
- *Facer Unwind - Rolls of facer material are loaded on the front end of the lamination line. Two rolls of material are unwound and fed toward the laminator. The material will become the top and bottom of the finished product.*
- *Compounding - Raw materials are compounded and heated to form the polyol or B-side component of the product formulation. The isocyanate or A-side of the product formulation is heated and transferred through a separate line.*
- *Mixing Head and Pour Table - The A-side and B-side components are mixed with the blowing agent at the mixing head. At the pour table, the mixture is applied through the mixing head applicator and laid onto one layer of the facer material. The chemical reaction begins at this point in the process, and the second layer of the facer material is brought into contact with the foam mixture as it enters the laminator.*
- *Laminator - The chemical reaction transforms the liquid mixture into the rigid foam core as the product moves through the laminator. The laminator is used to control the thickness of the finished product as well as other characteristics such as cell formation, curing, and facer adhesion. The laminator can also be adjusted to form any tapered characteristics for finished polyiso boards.*
- *Trim and Cutting - The product is manufactured in a continuous process and must be trimmed and cut after exiting the laminator. A cross-cut saw and gang saw are used to cut the material down to either 4' or 8' finished lengths.*
- *Robot Stacker - A conveyor system moves the polyiso boards through the trimming and cutting process to the robot stacker. An initial quality check is performed as the boards are stacked in bundles.*
- *Packaging - The stacked bundles are transferred to a hooding machine where each bundle is individually wrapped with a plastic film. The factory packaging secures the product for warehouse storage and transport.*
- *Foot Station and Warehousing - The product identification labels are applied to each bundle. A forklift transfers the bundles from the end of the line to warehouse storage. Polyiso boards complete the curing process while stored in the warehouse.*
- *Quality Assurance and Control - Product samples are selected and subjected to various quality assurance and quality control (QA/QC) testing. The QA/QC is performed against applicable standards and internal controls for physical properties including initial R-value, compressive strength, and dimensional stability.*
- *Loading and Shipping - After QA/QC testing and storage in the warehouse, the bundles are transferred to the loading dock. Bundles are loaded onto flatbed trucks and secured for transport to jobsites or distribution locations.*

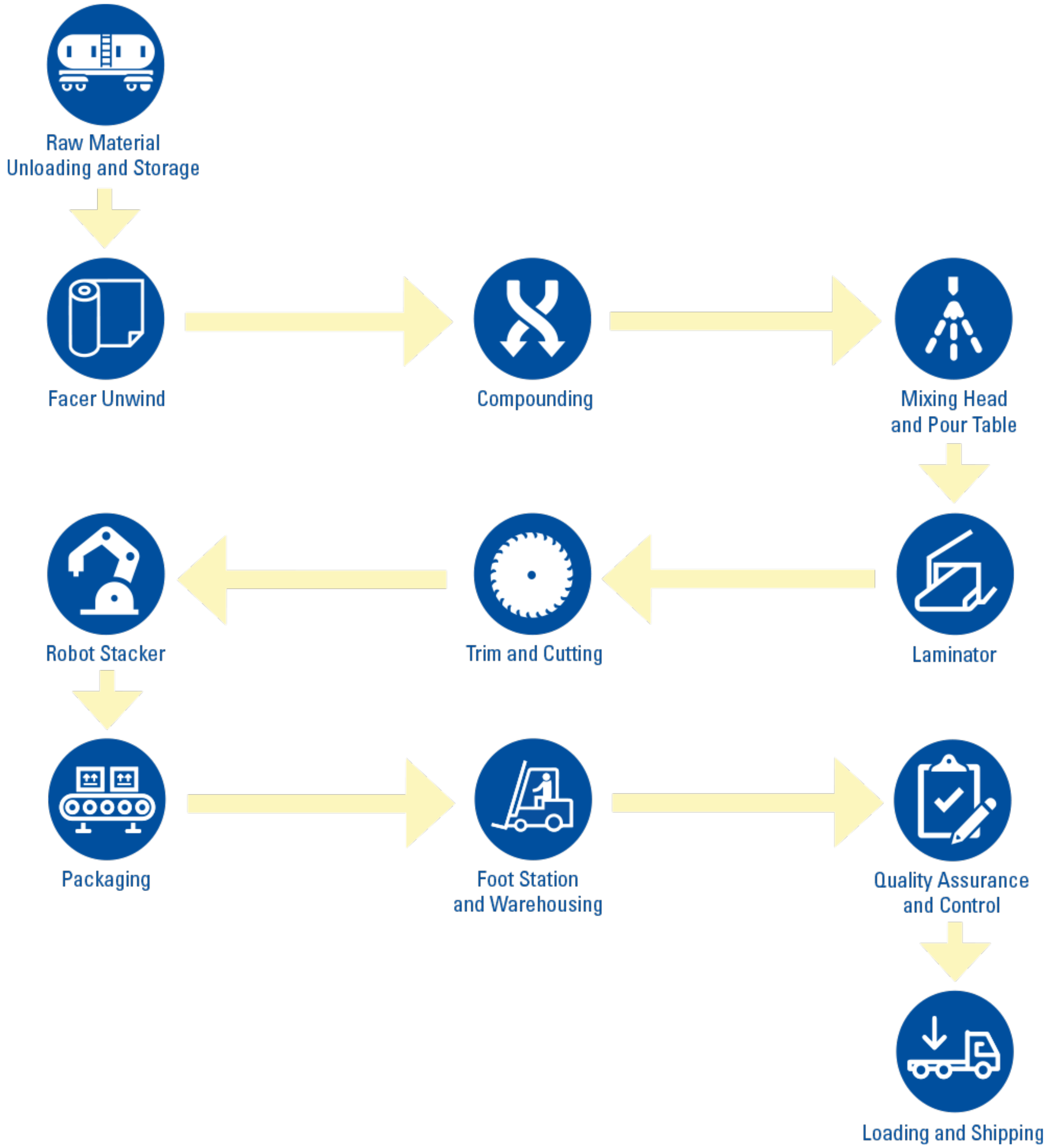


Figure 3: Illustration of the polyiso insulation manufacturing process.

2.6. PROPERTIES OF PRODUCT AS DELIVERED

The manufactured polyiso roof 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) or 1.2 m by 1.2 m (4 feet by 4 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 roof insulation. Board thickness is typically 2.54 cm to 10.16 cm (1.0 to 4.0-inch thick).

2.7. PACKAGING

Bundles of polyiso roof 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. The bundles may be stacked on wood pallets.

Table 3: Amount of packaging materials for polyiso Insulation boards per product reference service life (RSL)*.

Materia	Roof - CGF	Roof - GRF	Unit
Polyethylene	1.79E-02	1.19E-02	kg/m^2
Wood	4.05E-03	1.19E-03	kg/m^2

* : RSL is the lifetime of the product (RSL = 40 years for roof products.)

2.8. TRANSPORTATION

The polyiso roof 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 the production facility is 738 km (458 miles). Additional transportation details are reported in Table 8 in the life cycle assessment scenario section of the EPD.

2.9. PRODUCT INSTALLATION

Upon delivery to the jobsite, the bundles of polyiso are unloaded from the truck to the rooftop using a crane or all terrain forklift, all packaging is removed (assumed to be landfilled), and the individual roof insulation boards are placed on the roof deck by a roofing crew. The polyiso roof insulation boards are secured to the roof deck prior to the installation of the roofing membrane. 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 2% product loss as prescribed by the PCR.[2] Additional installation details are reported in Table 9 in the life cycle assessment scenario section of the EPD.

2.10. USE CONDITIONS

The use phase follows the installation of polyiso roof insulation boards or HD roof cover boards. In a roofing system, the insulation is located on top of a roof deck and below the roof membrane. If HD roof cover board is part of the system, it is located on top of insulation and below the roof membrane. The roof membrane, when installed properly and adequately maintained, protects the insulation and the HD cover board from environmental elements (i.e., rainwater) and weather during its use. The HD roof cover board offers additional protection (i.e., impact resistance) for the insulation below it. Therefore, it is expected that polyiso roof insulation and HD roof cover boards will not sustain damage that affects its performance and function and does not require maintenance.

2.11. PRODUCT REFERENCE SERVICE LIFE AND BUILDING ESTIMATED SERVICE LIFE

As defined in the governing PCR, the Building Estimated Service Life (ESL) is 75 years. The necessary steps for providing weather protection are specified by manufacturer installation instructions and are mandated by model building codes.

The roof membrane's useful life span is influenced by many variables including roof system design, quality of the installation, type and durability of the membrane, roof system component configuration and maintenance as well as weather conditions and events. Assuming that variables are sufficiently addressed through the membrane and the roof system design and installation, the insulation will serve its functional purpose for the 75-year life span of the building. However, the real-world reroofing scenarios, building owner tendencies, and the expected service life of roof membranes all indicate that reroofing activity will take place during the 75-year building ESL.

Reroofing activity may initially occur at 15-30 years after the installation of the original system and driven by recurring roof leaks that cannot be remedied by patch repairs of the membrane. When reroofing is required, options are available to address the need for a new roof membrane without the need to replace the insulation. The model building codes describe a "Roof Recover" as an acceptable reroofing practice, which occurs when a new roof covering is installed on top of the existing roof system without disturbing or removing the existing roof covering or the insulation below. Roof Recover, as defined by industry practices, involves visual examination and appropriate testing to ensure that all roof components, including insulation, have not sustained damage or deterioration. This approach allows the insulation to be reused instead of being disposed of into a landfill. The Roof Recover approach is a common practice in the roofing industry: it is permitted by model building codes and allows the service life of a roof system to be extended (without the need to replace the insulation). However, while the Roof Recover approach is a common practice, it is often not captured in reroofing studies available in the public domain, which typically contemplate a full roof replacement. Pertinent to this declaration, PIMA recognizes a 20-year life span for the original installation of the membrane followed by a Roof Recover, which extends the life of the original roof system to 40 years. This practice, and the PCR, establishes a **40-year product RSL** for polyiso roof insulation boards and HD roof cover boards. In the United States the model building codes allow a roof to be recovered only once. Where two roof membranes are installed on an existing roof, a reroofing process referred to as a "Roof Replacement" is required. This process involves the removal of all roof components down to the roof deck. Depending on the condition of the insulation or cover board, these materials can be reused on site, resold on secondary markets or landfilled. Typically, roof demolition is preferred to alleviate the labor required to separate materials for reuse. This study conservatively assumes all insulation is disposed in the landfill during a Roof Replacement. Therefore, the polyiso roof insulation boards' cradle-to-grave assessment incorporates all life cycle stage environmental impacts connected with the original building construction, a Roof Recover operation at 20 years, as well as the building's Roof Replacement operation at 40 years. This translates to 0.9 replacement cycles during the **75-year building ESL** (75-year ESL/40-year RSL -1 = 0.9 replacement cycles). In Canada, the National Model Building Codes do not provide guidance or limitations for recovers of existing roofs. Even though the age of roofs may surpass 40 years, the same roof replacement cycle of 40 years is assumed in this study for buildings in Canada.

2.12. RE-USE PHASE

If the product is still in good condition and has not passed its reference service life, it may be reused. No re-use is considered in this EPD.

2.13. DISPOSAL

At the end of the building's service life, the polyiso roof are assumed to be disposed of in a landfill and no recycling is considered. The boards are transported 161 km (100 miles) to landfill sites by truck for disposal. Additional disposal details are reported in the Transport to waste disposal (module C2) and Disposal of waste (module C4) tables presented in the scenario section.

3. LCA CALCULATION RULES

3.1. REFERENCE FLOW AND FUNCTIONAL UNIT

The selected functional unit (FU) for this study is:**1 m²** of installed insulation material with a thickness that gives an average thermal resistance **RSI = 1 m²K/W** and with a building service life of **75 years**.

Table 4 below summarizes the reference flows associated with the functional unit. Roof insulation boards RSI value represents the LTTR RSI value determined using CAN/ULC-S770 or ASTM C1303/1303M. Reference flows, which represent weighted average values, are separated shown per product reference service life (RSL) and per building estimated service life (ESL). The product weight per product RSL represents: 1 m^2 of product with RSI = 1m^2K/W without installation loss or replacement. The product weight per building ESL, on the other hand, represents: 1 m^2 of product with RSI = 1m^2K/W with installation loss and replacement.

For polyiso roof insulation boards, there is a 2% loss; hence, to fulfill the functional unit, additional polyiso roof insulation board must be produced. In addition to the installation loss, there is a replacement factor. The reference mass per ESL is calculated as follows:

$$ESL\ product\ weight\ (kg) = \frac{RSL\ product\ weight\ (kg)}{\left(100\% - Installation\ loss\ (\%)\right)} * (1 + Replacement)$$

For CGF polyiso roof insulation boards, this gives:

$$ESL\ product\ weight\ (kg) = \frac{1.812\ kg}{(100\% - 2\%)} * (1 + 0.9) = 3.512\ kg$$

Table 4: Reference flows of studied products per reference service life (RSL) and per building estimated service life (ESL).

Reference flows		Roof - CGF	Roof - GRF	Unit	Roof - CGF	Roof - GRF	Unit
RSL	**Product weight**	1.812	1.133	kg/m²	0.371	0.232	lb/ft²
	Facer weight	1.080	0.415	kg/m²	0.221	0.085	lb/ft²
	Foam weight	0.731	0.718	kg/m²	0.150	0.147	lb/ft²
	Thickness	25.3	25.3	mm	0.996	0.996	inch
	RSI / R-value	1.0	1.0	m² ·K/W	5.68	5.68	ft² °F·h/Btu
ESL	**Product weight**	3.512	2.197	kg/m²	0.719	0.450	lb/ft2
	Installation loss	2%	2%	%	2%	2%	%
	Replacement (ESL/RSL-1)	0.9	0.9		0.9	0.9	

3.2. PRODUCTION AVERAGE

Johns Manville manufacturing facilities located in in Bremen (IN), Cornwall (ON), Fernley (NV), Hazleton (PA), Hillsboro (TX), and Jacksonville (FL) participated in the product-specific EPD. A vertical mass-weighted average was calculated based on the LCA results obtained from 6 facilities, whichever their size, which provided their production data for the full 2023 calendar year. Products with the same application and facer type, but different compressive strength and foam formulation were grouped together. The potential environmental impact results are within ±13% when comparing manufacturer-average, product-average results with facility-specific, product-specific results. For confidentiality purposes, results are shown as manufacturer-average, even thought the grouping criteria is exceed by 3% for some impact categories. It should be noted that the potential environmental impact results remain within a ±10% change when comparing products grouped by compressive strength with those aggregated into a single group.

3.3. ESTIMATES AND ASSUMPTIONS

The table below presents the datasets selected to represent the polyiso foam raw materials.

Table 5: Datasets selected to represent polyiso insulation raw materials.

Material	Data source	Data Reference Year
MDI	American Chemistry Council (ACC), 2022, cradle-to-gate LCI study: LCIA results (mass and elemental alloc.)	2015 - 2017
Polyester Polyol	Primary data	2023
Blowing agent	Ecoinvent dataset 3.9.1: pentane production | pentane | Cutoff, U - RoW	2001 - 2022
Flame retardant	TCPP GABi database: Tris(2-chloroisopropyl)phosphate (TCPP) - US	2018
Surfactant	Ecoinvent 3.9.1 datasets (for 1 kg of surfactant) 0.4 kg polydimethylsiloxane production | polydimethylsiloxane | Cutoff, U – GLO 0.6 kg polyol production | polyol | Cutoff, U - RoW	2015 - 2022
Catalyst	Ecoinvent 3.9.1 datasets (for 1 kg of catalyst) 0.5 kg ethanolamine production | triethanolamine | Cutoff, U - RoW 0.29 kg potassium hydroxide production | potassium hydroxide | Cutoff, U - RoW USLCI dataset*: 0.31 kg Acetic acid, at plant/kg/RNA	2000 - 2022 1998 – 2022 2002
CGF Facer	Primary data	2023
GRF Facer	Primary data	2023

*Cut-off processes have been filled with ecoinvent data

3.4. SYSTEM BOUNDARIES

The system boundaries are **cradle-to-grave**, i.e., cover all life cycle stages as shown in Table 6.[2] Except for module B4, replacement, impacts for modules B2 – B7 shall be reported as zero (0) impact for all environmental indicators and inventory metrics. Figure 4 presents the process flow diagram for polyiso roof insulation boards. Neither renewable energy credits nor carbon credits are used within the scope of this project.

Table 6: Description of the system boundary life cycle stages and related information modules.

PRODUCTION STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END-OF-LIFE STAGE			
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
Extraction and Upstream Production	Transport to Factory	Manufacturing	Transport to site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	Deconstruction / Demolition	Transport to Waste Processing or Disposal	Waste Processing	Disposal of Waste
X	X	X	X	X	X	X	X	X *	X	X	X	X	X	X	X

Key: X = included; MND = module not declared (excluded).

*: Roofing applications have a reference service life of 40 years for a 75-year building estimated service life; hence, a replacement of 0.9 is considered.

Production (modules A1 to A3)

Extraction and upstream production (module A1): This module includes the extraction and transformation of raw materials needed to produce polyiso products.

Transport to factory (module A2): This module includes the transportation of raw materials from suppliers to the manufacturing facilities.

Manufacturing (module A3): This module includes water and energy (electricity, natural gas, diesel, propane) consumption for the manufacturing processes and building requirements (lighting, heating, cooling). Ancillary materials used in the polyiso manufacturing process and their transport from the suppliers to the manufacturing facilities have been considered here, as well as packaging materials to make the products ready for shipment. Blowing agent emissions from the production process and from the polyiso board cuttings are also included in this module, as well as the transport of waste to waste treatment and the waste treatment itself. The majority of the manufacturing waste is sent to landfill.

Construction (modules A4 to A5)

Delivery and installation: These modules included the delivery of the product to the client and their installation. Product loss during the installation of roof insulation boards is 2%.[2] Waste generated during installation, such as product loss and packaging, are ais considered landfilled. Transport and treatment of waste are included. It should be noted that the production (modules A1 to A3) and delivery (module A4) of lost products are included in module A5.

Use (modules B1 to B7)

Use: Module B1 includes pentane emissions during the use phase and module B4 includes replacement for roofing product applications. Modules B2, B3, B5, B6 and B7 are "null" for the purpose of the EPDs.

End-of-Life (modules C1 to C4)

End-of-life: This stage includes modules C2 and C4, transport to and treatment of waste at inert material landfill, respectively. Modules C1 and C3 modules are "null."

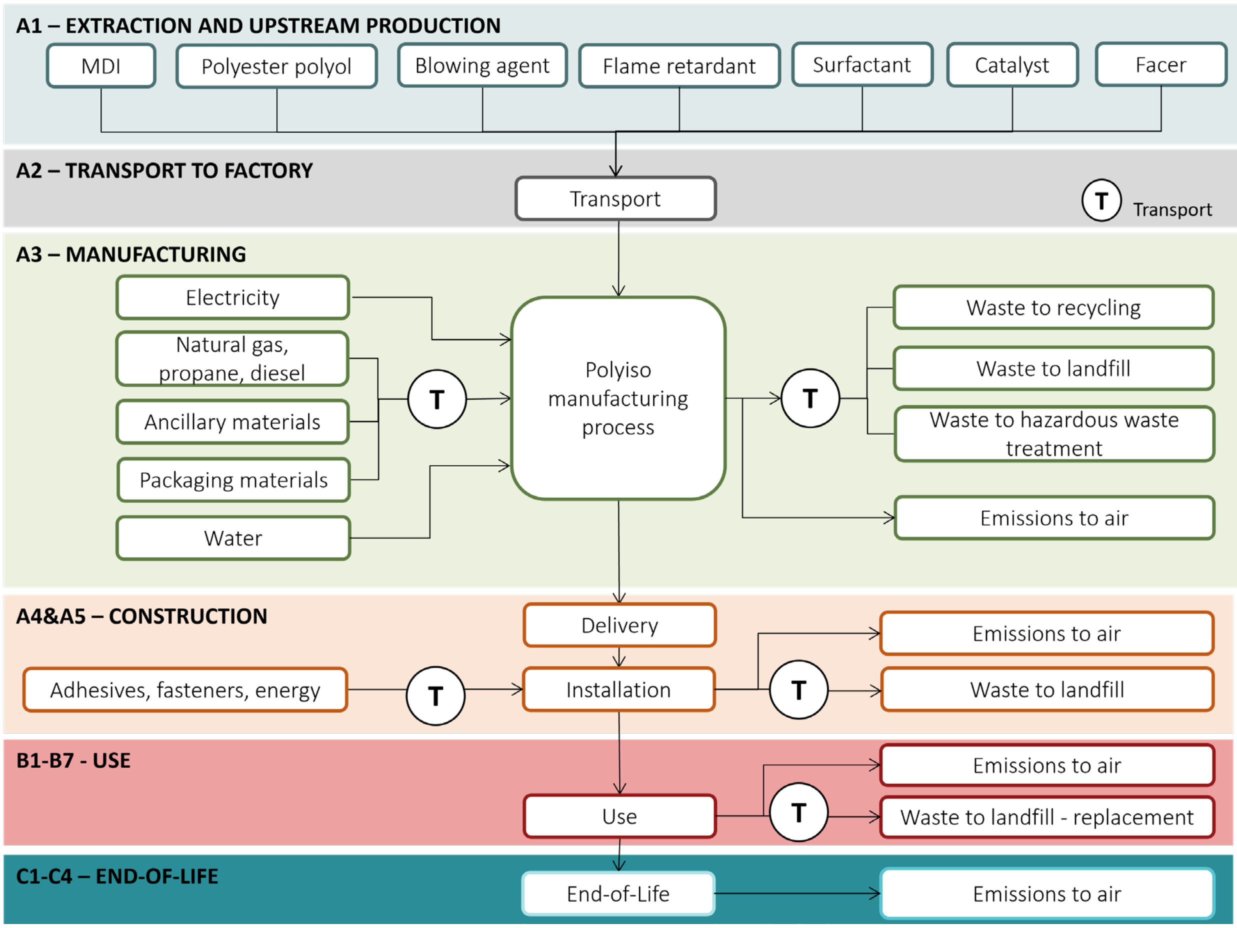


Figure 4: Cradle-to-grave LCA system boundaries of polyiso products.

3.5. CUT-OFF CRITERIA

According to ISO 21930:2017, cut-off rules shall not be applied in order to hide data. All data shall be included. In the case of insufficient data, the cut-off criteria shall be 1% of energy or 1% of total mass input and 1% of environmental impacts of the unit process. The total cut-off input flows per module shall be a maximum of 5% energy, mass and environmental impacts.

No known flows are deliberately excluded from this study.

For this study, no data on the construction, maintenance or dismantling of the capital assets, daily transport of employees, office work, business trips or other employee activities were included in the model. The model only takes into account the processes associated with infrastructures that are already included in the *ecoinvent* unit processes.

3.6. ALLOCATION

Whenever possible, allocation should be avoided by collecting data related to the process under study or by expanding the product system. When allocation cannot be avoided, according to UL Solutions Part B PCR, mass allocation should be used.[2]

Energy consumption, ancillary materials and packaging materials were provided for the entire manufacturing facilities; thus, **mass allocation** was used. Otherwise, no co-product allocation was required.

Waste processing of the material flows undergoing **recycling processes** are included up to the system boundary of the end-of-waste.[6] In other words, a **cut-off approach** was used as further processing of the recycled material is part of raw material preparation of another product system (open-loop recycling).

Blowing agent (pentane) emissions during the life cycle of the product were calculated from primary data and PCR blowing agent emission allocation factors to preserve mass balance. Thus, the calculated blowing agent emission allocation factors differ slightly from the ones presented in the UL Solutions Part B PCR for Building Envelope Thermal Insulation products[2] and are shown in the table below.

Table 7: Calculated pentane emission allocation factors per information module.

	A3	A5	B1	C4	Remains in material
Roof Polyiso Insulation Boards	7.2% - 10.4%	2%	18.8% - 19.5%	68.7% - 71.3%	0%

3.7. CALCULATION METHOD

The openLCA software v2.03 [12], an open-source software, was used to calculate the inventory and to assess potential environmental impacts associated with the inventoried emissions.

[Photo courtesy of Johns Manville]

3.8. DATA SOURCES AND QUALITY REQUIREMENTS

Data Source/Quality Parameter	Data Source/Quality Discussion
Source of manufacturing data (primary data)	Manufacturing data was collected from Johns Manville six polyiso manufacturing plants located in North America for the 2023 production year. This data included: total annual mass of products produced at the manufacturing plants; specific product composition; raw materials and fuels entering the product production process; transport distance of materials and fuels, electricity consumption, water consumption, emissions to the environment at the manufacturing plant; and packaging.
Source of secondary data (background data)	MDI: American Chemistry Council (ACC), 2022, cradle-to-gate LCI study: LCIA results (mass and elemental allocation) Polyester polyol and facer: primary data Flame retardant: GaBi Catalyst: ecoinvent 3.9.1 and US LCI Pentane, surfactant, energy use, transport, waste treatment and packaging: ecoinvent 3.9.1
Geographical representativeness	Manufacturing facilities are based in North America; hence electricity consumption is based on each facility’s regional grid mix and natural gas consumption from the Canadian or US high-pressure natural gas market as appropriate. Geographical correlation of the material supply and the selected datasets are largely representative of the same area. When this was not possible, datasets representing a larger geographical area were used.
Temporal representativeness	Primary data was collected from the polyiso manufacturers and their specific facilities for the full 2023 calendar year. Datasets selected were almost all from a time period ending within the last ten years.
Technological representativeness	Primary data, obtained from the manufacturer, is representative of the current technologies and materials used by their company.
Completeness	All relevant process steps were considered and modeled to satisfy the goal and scope. No known flows were cut off.
Consistency	The same data was collected from all facilities, the same data treatment was applied to all facilities and, as a vertical mass-weighted average was calculated based on the LCA results obtained from 6 facilities, the same model was used for all facilities; hence, the consistency of this study is high.
Reproducibility	Given access to the LCA report and the quality-checked primary data of all facilities, an independent practitioner would be able to reproduce the results as calculation rules and model details are reported in detail in the LCA report.

4. LIFE CYCLE ASSESSMENT SCENARIO

4.1. TRANSPORT TO INSTALLATION SITE (MODULE A4)

Primary data was collected from each participating manufacturer regarding product transport to installation sites or distributors (transport distance and transport mode).

Table 8: Transport to building site assumptions (module A4).

Name	Manufactured boards	Unit
Fuel type	Diesel	
Vehicle type*	53' Tractor-trailer	
Transport distance**	738	km
Capacity utilization (including empty runs, mass-based)	50	%
Gross density of products transported	Roof – CGF insulation: 71.6 Roof – GRF insulation: 44.8	kg/m^3
Capacity utilization volume factor	1	

* Modelled using ecoinvent 3.9.1 dataset "transport, freight, lorry >32 metric ton, EURO6 | transport, freight, lorry >32 metric ton, EURO6 | Cutoff, U – RoW."

** From primary data, represents the mass weighted average.

4.2. INSTALLATION (MODULE A5)

UL Solutions Part B PCR is prescriptive on the installation assumptions (ancillary materials, electricity consumption, diesel fuel consumption) and product losses during installation.[2] All studied products have the same installation assumptions and transport distance from building site to waste processing. Details are presented in Table 9. Waste product and packaging are considered non-hazardous waste sent to inert landfill by refuse truck over 161 km. Packaging waste, a low fraction of the Construction & Demolition (C&D) waste, is difficult to separate and recover; thus, packaging waste is considered all sent to landfill.[9] Biogenic carbon is considered emitted from packaging wood pallets and, apart from pentane emissions, no other VOC emissions are considered emitted in A5, nor were any VOC emissions tests performed.

Table 9: Installation into the building site assumption (module A5).

Name	Manufactured boards	Unit
Ancillary materials	0.0012 Fasteners 0.0012 Adhesive	kg
Electricity consumption	0.012	kWh
Diesel fuel for onboard generators	0.37	MJ
Product loss	2%	%
Pentane emissions	Roof - CGF insulation: 0.00098 Roof – GRF insulation: 0.00113	kg
Product waste at the construction site before waste processing, generated by product installation	Roof – CGF insulation: 0.037 Roof – GRF insulation: 0.023	kg
LDPE Packaging waste	Roof -CGF insulation: 0.022 Roof – GRF insulation: 0.013	kg
Biogenic carbon contained in packaging*	Roof – CGF insulation: 0.008 Roof – GRF insulation: 0.002 Polyiso HD roof cover boards: 0.053	kg CO_2

* Wood pallets are considered to contain 50% carbon.

4.3. USE (MODULE B1)

The use phase only includes pentane emissions. According to the UL Solutions Part B PCR: Building Insulation,[2] 21.5% of the pentane in the installed product is emitted during the use phase and the balance at disposal (module C4).

4.4. REPLACEMENT (MODULE B4)

Roofing products, which have a reference service life (RSL) of 40 years, have a replacement cycle of 0.9. The estimated service life (ESL) of the building is 75 years. The replacement cycle in Table 10 represents the additional quantity of product produced in the production life cycle stage (modules A1-A3) necessary to meet replacement needs throughout the building's estimated service life (ESL), their transport to the installation site, their installation, as well as the end-of-life stage of the original boards replaced. In other words, the replacement module B4 is equal to the sum modules C1, C2, C3 and C4 multiplied by 1/0.9 and the sum modules A1, A2, A3, A4 and A5 multiplied by 0.9. Refer to appropriate module scenario of the report for detailed information.

Table 10: Replacement (module B4).

Name	Roofing application	Unit
Building's Estimated Service Live (ESL)	75	years
Reference Service Life (RSL)	40	years
Replacement cycle*	0.9	N/A

* Replacement cycle is calculated with the following equation (ESL/RSL) – 1. Result is rounded-up to the nearest tenth of the building's ESL.

4.5. END-OF-LIFE (MODULES C1-C4)

At their end-of-life, polyiso roof insulation boards are removed and transported to a landfill.

Polyiso insulation boards do not require waste processing. In addition potential environmental impacts associated with deconstruction of polyiso boards are considered negligible compared to the potential environmental impacts of the deconstruction of the whole building; hence, module C1 is considered null.

Table 11: End-of-life (modules C1-C4)

<table>
<tr><th colspan="2">Name</th><th>Manufactured boards</th><th>Unit</th></tr>
<tr><td colspan="2">Transport</td><td>161</td><td>km</td></tr>
<tr><td>Collection process *</td><td>Collected with mixed construction waste</td><td>Roof - CGF insulation: 1.802
Roof - GRF insulation: 1.123</td><td>kg</td></tr>
<tr><td>Disposal **</td><td>Product for final disposal (100% landfill)</td><td>Roof - CGF insulation: 1.767
Roof - GRF insulation: 1.084</td><td>kg</td></tr>
<tr><td colspan="2">Blowing agent emissions</td><td>Roof - CGF insulation: 0.035
Roof - GRF insulation: 0.039</td><td>kg</td></tr>
</table>

* Mass adjusted to account for mass loss due to off-gassing in module B1. Values per product reference service life (RSL).

**Mass adjusted to account for mass of pentane loss in module B1 and module C4, which is 100% of the pentane in product. Values per product reference service life (RSL).

5. LIFE CYCLE ASSESSMENT RESULTS

5.1. RESULTS TABLES

It should be noted that Life Cycle Impact Assessment (LCIA) results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

The reported six impact categories 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.

The tables below present the LCIA results according to the product functional unit using the TRACI 2.2 methodology (GWP from IPCC AR5, ADF-ff from CML 4.8), as well as primary energy consumption, consumption of renewable and non-renewable materials, water consumption, and waste generation. EPA updated TRACI in 2021 to include spatially-specific eutrophication factors. All other indicators remain the same from version 2.1; hence, as an optional additional indicator, Eutrophication Potential from TRACI 2.1 is shown for information purposes. It should be noted that, except for roofing applications where replacement impacts are reported in module B4, modules B2 – B7 are reported as zero, as are modules C1 and C3 as they have no associated impacts.

TRACI 2.2 potential impact indicators
GWP: Global Warming Potential; **ADP-ff**: Abiotic Resource Depletion Potential of Non-Renewable (Fossil) Energy Resources; **AP**: Acidification Potential; **EP_f**: Eutrophication Potential – Freshwater; **EP_m**: Eutrophication Potential – Marine; **ODP**: Ozone Layer Depletion Potential; **SFP**: Smog Formation Potential.
Resource use
RPR_E: Renewable Primary Resources Used as Energy Carrier (Fuel); **RPR_M**: Renewable Primary Resources with Energy Content Used as Material; **RPR_T**: Renewable Primary Resources Total; **$NRPR_E$**: Non-Renewable Primary Resources Used as Energy Carrier (Fuel); **$NRPR_M$**: Non-Renewable Primary Resources with Energy Content Used as Material; **$NRPR_T$**: Non-Renewable Primary Resources Total; **SM**: Secondary Materials; **RSF**: Renewable Secondary Fuels; **NRSF**: Non-Renewable Secondary Fuels; **RE**: Recovered Energy; **FW**: Use of Net Fresh Water Resources.
Output flows and waste categories
HWD: Hazardous Waste Disposed; **NHWD**: Non-Hazardous Waste Disposed; **HLRW**: High-Level Radioactive Waste, Conditioned, to Final Repository; **ILLRW**: Intermediate and Low-Level Radioactive Waste, Conditioned, to Final Repository; **CRU**: Components for Re-Use; **MFR**: Materials for Recycling; **MER**: Materials for Energy Recovery; **EE**: Exported Energy.
Additional indicator – TRACI 2.1
EP: Eutrophication Potential

Table 12: Cradle-to-grave LCA results for 1 m^2 of installed polyiso roof insulation boards, CGF, with a thickness that gives an average thermal resistance RSI = 1 m²K/W and with a building service life of 75 years.

Environmental indicator		Unit	A1 (per m2)	A2 (per m2)	A3 (per m2)	A4 (per m2)	A5 (per m2)	B1 (per m2)	B4 (per m2)	C2 (per m2)	C4 (per m2)
IPCC AR5 and TRACI 2.2	GWP[1]	kg CO_2 eq.	3.89E+00	2.45E-01	2.83E-01	1.34E-01	1.56E-01	0.00E+00	4.65E+00	3.63E-01	9.70E-03
	GWP_{fossil}[1]	kg CO_2 eq.	3.86E+00	2.45E-01	2.82E-01	1.34E-01	1.56E-01	0.00E+00	4.62E+00	3.63E-01	9.70E-03
	$GWP_{biogenic}$[1]	kg CO_2 eq.	6.71E-03	7.97E-05	2.97E-04	3.97E-05	1.92E-04	0.00E+00	6.63E-03	3.69E-05	3.93E-06
	$GWP_{LU\&LUT}$[1]	kg CO_2 eq.	2.13E-02	1.47E-04	5.45E-04	6.92E-05	4.78E-04	0.00E+00	2.03E-02	4.56E-05	5.75E-06
	ADP-ff[2]	MJ, LHV	7.78E+01	3.40E+00	4.44E+00	2.03E+00	2.64E+00	0.00E+00	8.68E+01	4.70E+00	2.40E-01
	AP	kg SO_2 eq.	1.30E-02	1.52E-03	5.40E-04	3.21E-04	7.43E-04	0.00E+00	1.66E-02	1.80E-03	6.53E-05
	EP_f	kg P eq.	7.10E-04	2.17E-05	8.67E-05	1.07E-05	2.40E-05	0.00E+00	7.76E-04	6.37E-06	7.58E-07
	EP_m	kg N eq.	8.83E-03	1.55E-03	3.46E-04	2.39E-04	7.36E-04	0.00E+00	1.31E-02	2.21E-03	7.11E-05
	ODP	kg CFC-11 eq.	2.10E-06	4.09E-09	2.11E-09	2.47E-09	4.42E-08	0.00E+00	1.94E-06	5.98E-09	2.97E-10
	SFP	kg O_3 eq.	2.27E-01	3.95E-02	1.37E-02	6.74E-03	2.02E-02	2.39E-02	3.91E-01	6.01E-02	4.32E-02
Resource use	RPR_E[3]	MJ, LHV	2.55E+00	6.76E-02	5.90E-01	2.90E-02	9.32E-02	0.00E+00	3.02E+00	2.07E-02	2.32E-03
	RPR_M[4]	MJ, LHV	1.13E-02	0.00E+00	0.00E+00	0.00E+00	2.30E-04	0.00E+00	1.04E-02	0.00E+00	0.00E+00
	RPR_T	MJ, LHV	2.56E+00	6.76E-02	5.90E-01	2.90E-02	9.34E-02	0.00E+00	3.03E+00	2.07E-02	2.32E-03
	$NRPR_E$[5]	MJ, LHV	4.86E+01	3.45E+00	5.29E+00	2.04E+00	2.08E+00	0.00E+00	6.08E+01	4.69E+00	2.41E-01
	$NRPR_M$[6]	MJ, LHV	3.41E+01	0.00E+00	0.00E+00	0.00E+00	7.24E-01	0.00E+00	3.14E+01	0.00E+00	0.00E+00
	$NRPR_T$	MJ, LHV	8.27E+01	3.45E+00	5.29E+00	2.04E+00	2.80E+00	0.00E+00	9.22E+01	4.69E+00	2.41E-01
	SM	kg	3.52E-02	0.00E+00	0.00E+00	0.00E+00	7.18E-04	0.00E+00	3.23E-02	0.00E+00	0.00E+00
	RSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	NRSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	FW[7]	m³	2.77E-02	5.05E-04	2.06E-03	2.93E-04	8.69E-04	0.00E+00	2.88E-02	2.28E-04	2.54E-04
Output flows and waste categories	HWD[8]	kg	2.71E+00	1.17E-01	4.57E-01	5.85E-02	1.04E-01	0.00E+00	3.14E+00	3.39E-02	4.04E-03
	NHWD[9]	kg	5.42E-01	1.90E-01	3.18E-02	1.74E-01	7.63E-02	0.00E+00	2.71E+00	2.28E-02	1.59E+00
	HLRW[10]	m³	5.63E-09	4.93E-11	1.21E-09	2.41E-11	1.81E-10	0.00E+00	6.41E-09	1.88E-11	1.89E-12
	ILLRW[11]	m³	4.40E-08	2.63E-10	3.50E-09	1.27E-10	1.17E-09	0.00E+00	4.42E-08	9.61E-11	1.02E-11
	CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MFR	kg	5.18E-02	0.00E+00	4.91E-03	0.00E+00	1.16E-03	0.00E+00	5.21E-02	0.00E+00	0.00E+00
	MER	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	EE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Additional indicator – TRACI 2.1											
	EP	kg N eq.	1.01E-02	2.76E-04	7.30E-04	1.16E-04	3.27E-04	0.00E+00	1.06E-02	1.89E-04	1.12E-05

Table 13: Cradle-to-grave LCA results for 1 m² of installed polyiso roof insulation boards, GRF, with a thickness that gives an average thermal resistance RSI = 1 m²K/W and with a building service life of 75 years.

Environmental indicator		Unit	A1 (per m2)	A2 (per m2)	A3 (per m2)	A4 (per m2)	A5 (per m2)	B1 (per m2)	B4 (per m2)	C2 (per m2)	C4 (per m2)
IPCC AR5 and TRACI 2.2	GWP(1)	kg CO_2 eq.	3.05E+00	1.09E-01	1.81E-01	8.36E-02	1.29E-01	0.00E+00	3.46E+00	2.26E-01	5.95E-03
	GWP_{fossil}(1)	kg CO_2 eq.	2.97E+00	1.08E-01	1.81E-01	8.36E-02	1.27E-01	0.00E+00	3.38E+00	2.26E-01	5.95E-03
	$GWP_{biogenic}$(1)	kg CO_2 eq.	6.38E-02	3.31E-05	1.63E-04	2.48E-05	1.35E-03	0.00E+00	5.89E-02	2.30E-05	2.41E-06
	$GWP_{LU\&LUT}$(1)	kg CO_2 eq.	2.04E-02	6.85E-05	2.16E-04	4.33E-05	4.51E-04	0.00E+00	1.91E-02	2.84E-05	3.53E-06
	ADP-ff(2)	MJ, LHV	6.31E+01	1.46E+00	2.73E+00	1.27E+00	2.18E+00	0.00E+00	6.71E+01	2.93E+00	1.47E-01
	AP	kg SO_2 eq.	8.92E-03	1.03E-03	3.97E-04	2.01E-04	6.22E-04	0.00E+00	1.13E-02	1.12E-03	4.01E-05
	EP_f	kg P eq.	7.08E-04	8.71E-06	5.85E-05	6.71E-06	2.29E-05	0.00E+00	7.29E-04	3.97E-06	4.65E-07
	EP_m	kg N eq.	6.06E-03	9.46E-04	2.21E-04	1.50E-04	6.35E-04	0.00E+00	8.78E-03	1.37E-03	4.36E-05
	ODP	kg CFC-11 eq.	2.26E-06	1.79E-09	1.55E-09	1.54E-09	4.73E-08	0.00E+00	2.09E-06	3.73E-09	1.82E-10
	SFP	kg O_3 eq.	1.53E-01	2.39E-02	1.09E-02	4.21E-03	1.77E-02	2.66E-02	2.83E-01	3.74E-02	4.72E-02
Resource use	RPR_E(3)	MJ, LHV	2.45E+00	2.73E-02	2.40E-01	1.82E-02	8.26E-02	0.00E+00	2.55E+00	1.29E-02	1.42E-03
	RPR_M(4)	MJ, LHV	5.38E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-01	0.00E+00	4.94E+00	0.00E+00	0.00E+00
	RPR_T	MJ, LHV	7.83E+00	2.73E-02	2.40E-01	1.82E-02	1.92E-01	0.00E+00	7.49E+00	1.29E-02	1.42E-03
	$NRPR_E$(5)	MJ, LHV	3.84E+01	1.48E+00	3.38E+00	1.28E+00	1.71E+00	0.00E+00	4.50E+01	2.92E+00	1.48E-01
	$NRPR_M$(6)	MJ, LHV	3.12E+01	0.00E+00	0.00E+00	0.00E+00	6.65E-01	0.00E+00	2.87E+01	0.00E+00	0.00E+00
	$NRPR_T$	MJ, LHV	6.96E+01	1.48E+00	3.38E+00	1.28E+00	2.38E+00	0.00E+00	7.37E+01	2.92E+00	1.48E-01
	SM	kg	4.64E-01	0.00E+00	0.00E+00	0.00E+00	9.46E-03	0.00E+00	4.26E-01	0.00E+00	0.00E+00
	RSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	NRSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	FW(7)	m³	1.93E-02	2.00E-04	9.97E-04	1.83E-04	6.62E-04	0.00E+00	1.96E-02	1.42E-04	1.56E-04
Output flows and waste categories	HWD(8)	kg	2.48E+00	4.69E-02	3.06E-01	3.66E-02	9.42E-02	0.00E+00	2.69E+00	2.11E-02	2.48E-03
	NHWD(9)	kg	2.57E-01	6.70E-02	2.46E-02	1.09E-01	4.63E-02	0.00E+00	1.55E+00	1.42E-02	9.76E-01
	HLRW(10)	m³	5.34E-09	1.98E-11	5.68E-10	1.51E-11	1.61E-10	0.00E+00	5.51E-09	1.17E-11	1.16E-12
	ILLRW(11)	m³	4.42E-08	1.05E-10	2.87E-09	7.92E-11	1.16E-09	0.00E+00	4.37E-08	5.98E-11	6.23E-12
	CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MFR	kg	0.00E+00	0.00E+00	7.43E-03	0.00E+00	1.52E-04	0.00E+00	6.83E-03	0.00E+00	0.00E+00
	MER	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	EE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Additional indicator – TRACI 2.1											
	EP	kg N eq.	7.96E-03	1.26E-04	4.87E-04	7.28E-05	2.71E-04	0.00E+00	8.17E-03	1.18E-04	6.87E-06

Table notes

(1) GWP 100, excludes biogenic CO_2 removals and emissions associated with biobased products and packaging; 100-year time horizon GWP factors are provided by the IPCC 2013 Fifth Assessment Report (AR5). $GWP_{biogenic}$ includes biogenic methane emissions to air, while $GWP_{LU\&LUT}$ includes carbon dioxide emissions to air from land transformation and to soil or biomass stock, as well as methane emissions to air from soil or biomass stock.
(2) Abiotic Resource Depletion Potential of non-renewable (fossil) energy resources (ADP-ff, in MJ, LHV) is based on CML-baseline, v4. August 2016.
(3) $RPR_E = RPR_T - RPR_M$, where RPR_T is equal to the value for renewable energy obtained using the CED methodology (LHV).
(4) Calculated as per ACLCA ISO 21930 Guidance, 6.2 Renewable primary resources with energy content used as a material, RPR_M.
(5) $NRPR_E = NRPR_T - NRPR_M$, where $NRPR_T$ is equal to the value for non-renewable energy obtained using the CED methodology (LHV).
(6) Calculated as per ACLCA ISO 21930 Guidance, 6.4 Non-renewable primary resources with energy content used as a material, $NRPR_M$.
(7) Represents the use of net fresh water calculated from life cycle inventory results, i.e., water consumption using ReCiPe Midpoint (E) 2016.
(8) Calculated from life cycle inventory results, based on datasets classified under "treatment and disposal of hazardous waste." The manufacturer does not generate hazardous waste.
(9) Calculated from life cycle inventory results, based on waste that is neither "hazardous" nor "radioactive" and EPD values.
(10) Calculated from life cycle inventory results, based on ecoinvent waste flow "high-level radioactive waste for final repository." The manufacturer does not generate radioactive waste.
(11) Calculated from life cycle inventory results, based on ecoinvent waste flow "low-level radioactive waste for final repository." The manufacturer does not generate radioactive waste.

5.2. INTERPRETATION

This section details the contribution to the potential environmental impacts and resource use of the different information modules. As can be seen from the figures below, replacement (module B4) is the main contributor to all potential impact categories, except ozone layer depletion (ODP), as well as renewable and non-renewable resource consumption. It should be noted that module B4 is equal to the replacement factor times the sum of modules A1-A5 plus the sum of modules C1-C4 of the initial installed product; hence, extraction and upstream production module (module A1) is, in fact, the main contributor to all potential impact categories, as well as renewable and non-renewable resource consumption. Within module A1, for all potential environmental impact indicators except for ozone layer depletion potential (ODP), MDI, polyol and facer materials are the ones contributing the most to the results. For ODP, it is surfactants.

The sensitivity analysis indicated that variations in foam density, facer density, and the quantities of MDI, polyol, and surfactants influence the potential environmental impacts across one or more impact categories. These sensitive parameters affect the quantity of raw materials used, which the contribution analysis identified as the primary drivers of environmental impacts in several categories.

Therefore, modifications to the quantity of datasets selected to represent the various polyiso raw materials—particularly facer material, MDI, polyol, and surfactants—may alter the results.

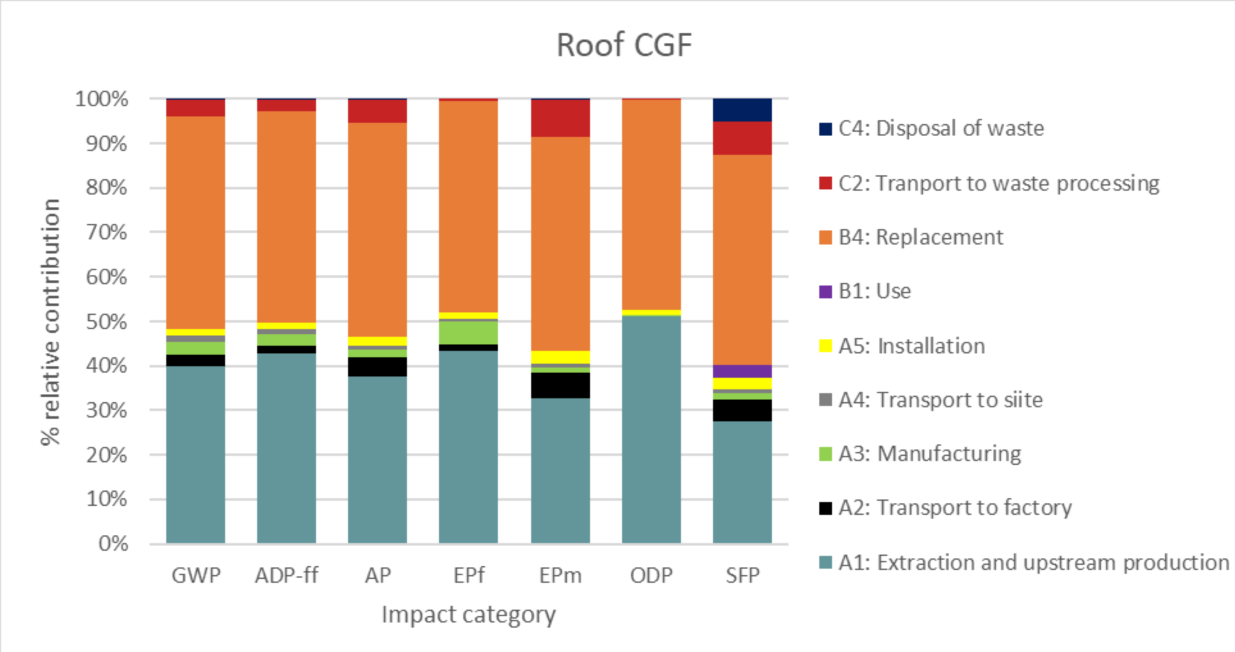


Figure 5: Contribution of life cycle information modules to the potential environmental impacts of 1m² of installed polyiso roof insulation board, CGF, for 75 years.

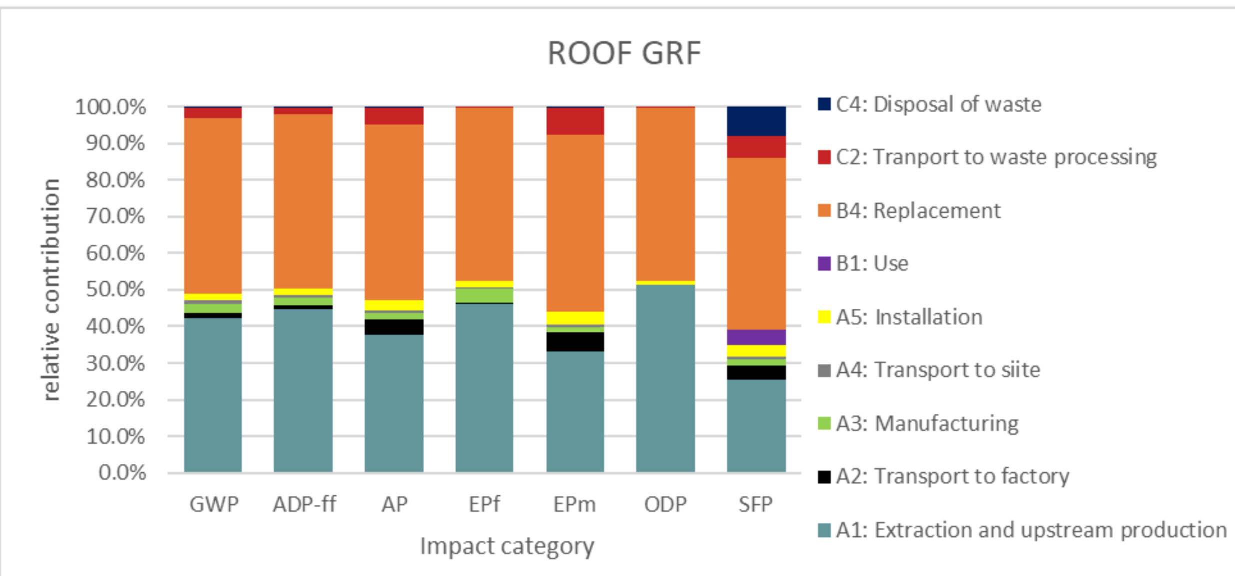


Figure 6: Contribution of life cycle information modules to the potential environmental impacts of 1m² of installed polyiso roof insulation board, GRF, for 75 years.

GWP: Global Warming Potential; **ADP-ff**: Abiotic Resource Depletion Potential of Non-Renewable (Fossil) Energy Resources; **AP**: Acidification Potential; **EP$_f$**: Eutrophication Potential – Freshwater; **EP$_m$**: Eutrophication Potential – Marine; **ODP**: Ozone Layer Depletion Potential; **SFP**: Smog Formation Potential.

6. ADDITIONAL ENVIRONMENTAL INFORMATION

6.1. CONTENT OF REGULATED HAZARDOUS SUBSTANCES

Polyiso products contain pentane or pentane blends blowing agent (5.2% - 7.1%).

6.2. RELEASE OF DANGEROUS SUBSTANCES FROM CONSTRUCTION PRODUCTS

Pentane and pentane blends blowing agent is considered to off-gas very slowly over years/decades during the use and the end-of-life of polyiso products. Freshly expanded or heated foam may off-gas some pentane-blowing agent, which is heavier than air and may accumulate to ignitable concentrations if stored inside a sealed container or within confined areas. Installation methods which include cutting and mechanical fastening may release the blowing agent retained in the product. Provide adequate ventilation to assure localized concentrations in release areas are maintained below the lower flammability limit. Good housekeeping and controlling of dust are necessary for safe handling of products.

Fire Performance: The fire performance of low-slope roof assemblies is evaluated using assembly tests (that include the roof deck and all materials above it) with respect to both external and internal fire exposure. The fire exposures in tests simulate the type of fire exposure a roof may encounter during its service life, including interior building fires or exterior hazards. The resistance of a roof system to external fire exposure is evaluated using ASTM E108 “Standard Test Methods for Fire Tests of Roof Coverings,” UL 790 “Standard Test Methods for Fire Tests of Roof Coverings” or the Canadian equivalent, CAN/ULC-S107 “Methods of Fire Tests of Roof Coverings.” The test methods provide a basis for comparing roof assemblies under a simulated exterior fire. Roof assemblies restricted to non-combustible decks require only the spread-of-flame test, while roof assemblies used on combustible decks are evaluated for spread of flame, intermittent flame, and the burning brand tests. Roof assemblies can achieve a Class A, B, or C classification. Class A designates the resistance to relatively severe fire-test exposure. Class B designates resistance to relatively moderate fire-test exposure. Class C designates resistance to relatively light fire-test exposure.

Fires can also originate within the building interior and roof system response to fire exposure originating from the interior of the building may be evaluated using NFPA 276 “Standard Method of Fire Test for Determining the Heat Release Rate of Roofing Assemblies with Combustible Above-Deck Roofing Components,” FM Approval 4470 “Single-Ply, Polymer-Modified Bitumen Sheet, Built-Up Roof (BUR) and Liquid Applied Roof: Assemblies for Use in Class 1 and non-combustible Roof Deck Construction,” UL 1256 “Fire Test of Roof Deck Construction,” or CAN/ULC-S126 “Standard Method of Test for Fire Spread Under Roof-Deck Assemblies.” The passing criteria is established by a limit-of-fuel contribution within a designated time period. Polyiso remains the only foam plastic roof insulation to earn FM Class 1 approval for direct-to-steel deck applications when tested in accordance with FM Approval 4470. Polyiso is also classified by UL under UL 1256 for direct-to-steel deck applications with both single-ply and asphalt-based roof coverings.

6.3. MARKET SCALING FACTORS AND ESTIMATED IMPACTS OF PRODUCTS AT DIFFERENT R-VALUE THAN THE FUNCTIONAL UNIT

For roof insulation boards, the environmental impact results in this EPD have been calculated for the functional unit of insulation, which has a surface area of 1 m^2 and a thermal resistance of RSI = 1 m^2K/W. In Imperial units, this thermal resistance, or R-value, is equivalent to 5.678 ft^2 °F h/Btu. To calculate total impact values for insulation at a specified project-determined thickness and R-value, whichever the environmental indicator or information module, with a specific facing material, the following equation may be used:

$$Results_{thx} = Foam\ results_{RSI=1} * \frac{th_x}{th_{RSI=1}} + Static\ facer\ results$$

Where:

$Results_{thx}$: Indicator value for a foam thickness equal to th_x.

$Foam\ results_{RSI=1}$: Indicator value for a foam thickness that give an RSI value of 1. See the appropriate product table below (in green).

th_x: Foam thickness (mm).

$th_{RSI=1}$: Foam thickness (mm) for an RSI value of 1. This value is presented in Table 4 and Table 15.

Static facer results: Indicator value for the static facer (both sides). See appropriate product table below (in orange).

For example, module A1 total global warming potential of the polyiso roof insulation board with coated glass facer for a thickness of 76.2mm (3 inch) is (Table 19 for *Foam results*, Table 15 for *Foam thickness for an RSI value of 1 ($th_{RSI=1}$)*, and Table 18 for *Static facer results*):

$$Results_{th=76.2mm} = 2.11E+00 * \frac{76.2}{25.3} + 1.78+00 = 8.12E+00\ kg\ CO_2\ eq./m^2$$

Table 14: Polyiso insulation board RSI value by foam thickness.

Thickness	LTTR RSI (R-Value) m^2 K/W (ft^2 °F h/Btu)
Mm (inch)	Roof
25.4 (1.0-inch)	1.00 (5.69)
50.8 (2.0-inch)	2.01 (11.40)
76.2 (3.0-inch)	3.06 (17.36)
101.6 (4.0-inch)	4.14 (23.50)

Table 15: Polyiso insulation board thickness for RSI =1 by product type.

Product	Thickness	Unit
Roof - CGF	25.3	mm
Roof- GRF	25.3	mm

For roof insulation, an R-Value of 25, 30 or 35 ft² °F h/Btu is most often required and, for polyiso products, fulfilled using two layers of polyiso roof insulation boards. The two tables below present the global warming potential (GWP) results for the most common product used on the market to achieve the typical R-values for roof applications.

Table 16: Global warming potential (GWP) for two layers of polyiso roof insulation board with coated glass facer (CGF) at designed thermal insulation (R-value).

Thickness per layer	RSI (R-Value) m^2 K/W (ft^2 °F h/Btu)	A1	A2	A3	A4	A5	B1	B4	C2	C4
mm (inch)	Roof - CGF	kg CO2 eq./m^2								
52.5 (2.1-inch)	4.40 (**R25**)	1.23E+01	7.03E-01	8.15E-01	3.83E-01	4.28E-01	0.00E+00	1.44E+01	1.04E+00	2.75E-02
62.9 (2.5-inch)	5.28 (**R30**)	1.40E+01	7.84E-01	9.09E-01	4.27E-01	4.72E-01	0.00E+00	1.63E+01	1.16E+00	3.06E-02
73.2 (2.9-inch)	6.16 (**R35**)	1.57E+01	8.65E-01	1.00E+00	4.71E-01	5.15E-01	0.00E+00	1.82E+01	1.28E+00	3.37E-02

Table 17: Global warming potential (GWP) for two layers of polyiso roof insulation board with glass reinforced cellulosic facer (GRF) at designed thermal insulation (R-value).

Thickness per layer	RSI (R-Value) m^2 K/W (ft^2 °F h/Btu)	A1	A2	A3	A4	A5	B1	B4	C2	C4
mm (inch)	Roof - GRF	kg CO2 eq./m^2								
52.5 (2.1-inch)	4.40 (**R25**)	1.06E+01	3.65E-01	6.15E-01	2.81E-01	3.70E-01	0.00E+00	1.19E+01	7.59E-01	1.98E-02
62.9 (2.5-inch)	5.28 (**R30**)	1.23E+01	4.22E-01	7.11E-01	3.24E-01	4.13E-01	0.00E+00	1.37E+01	8.75E-01	2.28E-02
73.2 (2.9-inch)	6.16 (**R35**)	1.40E+01	4.78E-01	8.06E-01	3.68E-01	4.56E-01	0.00E+00	1.56E+01	9.91E-01	2.58E-02

[Photo courtesy of Johns Manville]

Table 18: Static facer results for polyiso roof insulation board with coated glass facer (CGF).

Environmental indicator		Unit	A1	A2	A3	A4	A5	B1	B4	C2	C4
			(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)
IPCC AR5 and TRACI 2.2	GWP[1]	kg CO_2 eq.	1.78E+00	1.46E-01	1.68E-01	7.97E-02	1.03E-01	0.00E+00	2.30E+00	2.18E-01	5.93E-03
	GWP_{fossil}[1]	kg CO_2 eq.	1.78E+00	1.46E-01	1.67E-01	7.97E-02	1.03E-01	0.00E+00	2.29E+00	2.18E-01	5.93E-03
	$GWP_{biogenic}$[1]	kg CO_2 eq.	2.86E-03	4.75E-05	1.71E-04	2.37E-05	1.09E-04	0.00E+00	2.92E-03	2.21E-05	2.40E-06
	$GWP_{LU\&LUT}$[1]	kg CO_2 eq.	4.82E-04	8.74E-05	3.22E-04	4.13E-05	4.66E-05	0.00E+00	9.16E-04	2.73E-05	3.51E-06
	ADP-ff[2]	MJ, LHV	2.60E+01	2.02E+00	2.64E+00	1.21E+00	1.43E+00	0.00E+00	3.32E+01	2.82E+00	1.47E-01
	AP	kg SO_2 eq.	6.13E-03	9.04E-04	3.19E-04	1.91E-04	5.58E-04	0.00E+00	8.54E-03	1.08E-03	3.99E-05
	EP_f	kg P eq.	3.07E-04	1.29E-05	5.15E-05	6.40E-06	1.47E-05	0.00E+00	3.58E-04	3.82E-06	4.64E-07
	EP_m	kg N eq.	3.95E-03	9.20E-04	2.04E-04	1.43E-04	5.88E-04	0.00E+00	6.75E-03	1.32E-03	4.34E-05
	ODP	kg CFC-11 eq.	2.73E-08	2.44E-09	1.25E-09	1.47E-09	1.77E-09	0.00E+00	3.50E-08	3.59E-09	1.82E-10
	SFP	kg O_3 eq.	1.04E-01	2.35E-02	5.51E-03	4.02E-03	1.51E-02	0.00E+00	1.78E-01	3.60E-02	1.13E-03
Resource use	RPR_E[3]	MJ, LHV	9.60E-01	4.02E-02	2.71E-01	1.73E-02	5.31E-02	0.00E+00	1.22E+00	1.24E-02	1.42E-03
	RPR_M[4]	MJ, LHV	1.13E-02	0.00E+00	0.00E+00	0.00E+00	2.30E-04	0.00E+00	1.04E-02	0.00E+00	0.00E+00
	RPR_T	MJ, LHV	9.72E-01	4.02E-02	2.71E-01	1.73E-02	5.33E-02	0.00E+00	1.23E+00	1.24E-02	1.42E-03
	$NRPR_E$[5]	MJ, LHV	2.70E+01	2.05E+00	3.14E+00	1.22E+00	1.48E+00	0.00E+00	3.47E+01	2.81E+00	1.47E-01
	$NRPR_M$[6]	MJ, LHV	2.81E+00	0.00E+00	0.00E+00	0.00E+00	8.49E-02	0.00E+00	2.61E+00	0.00E+00	0.00E+00
	$NRPR_T$	MJ, LHV	2.98E+01	2.05E+00	3.14E+00	1.22E+00	1.56E+00	0.00E+00	3.73E+01	2.81E+00	1.47E-01
	SM	kg	3.52E-02	0.00E+00	0.00E+00	0.00E+00	7.18E-04	0.00E+00	3.23E-02	0.00E+00	0.00E+00
	RSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	NRSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	FW[7]	m^3	1.26E-02	3.00E-04	1.22E-03	1.75E-04	5.31E-04	0.00E+00	1.37E-02	1.37E-04	1.56E-04
Output flows and waste categories	HWD[8]	kg	1.88E+00	6.97E-02	2.72E-01	3.49E-02	8.17E-02	0.00E+00	2.13E+00	2.03E-02	2.47E-03
	NHWD[9]	kg	4.03E-01	1.13E-01	1.93E-02	1.04E-01	4.76E-02	0.00E+00	1.71E+00	1.37E-02	9.73E-01
	HLRW[10]	m^3	3.14E-09	2.94E-11	7.21E-10	1.44E-11	1.20E-10	0.00E+00	3.64E-09	1.13E-11	1.15E-12
	ILLRW[11]	m^3	2.52E-08	1.56E-10	2.09E-09	7.55E-11	7.53E-10	0.00E+00	2.55E-08	5.76E-11	6.21E-12
	CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MFR	kg	5.18E-02	0.00E+00	3.05E-03	0.00E+00	1.12E-03	0.00E+00	5.04E-02	0.00E+00	0.00E+00
	MER	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	EE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Additional indicator – TRACI 2.1											
	EP	kg N eq.	4.89E-03	1.64E-04	4.33E-04	6.94E-05	2.08E-04	0.00E+00	5.32E-03	1.13E-04	6.85E-06

Table 19: Foam results for polyiso roof insulation boards without coated glass facer (CGF), with a thickness that gives an average thermal resistance RSI = 1 m²K/W.

Environmental indicator		Unit	A1	A2	A3	A4	A5	B1	B4	C2	C4
			(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)
IPCC AR5 and TRACI 2.2	GWP(1)	kg CO_2 eq.	2.11E+00	9.91E-02	1.15E-01	5.39E-02	5.36E-02	0.00E+00	2.35E+00	1.45E-01	3.77E-03
	GWP_{fossil}(1)	kg CO_2 eq.	2.08E+00	9.91E-02	1.15E-01	5.39E-02	5.31E-02	0.00E+00	2.33E+00	1.45E-01	3.77E-03
	$GWP_{biogenic}$(1)	kg CO_2 eq.	3.85E-03	3.23E-05	1.25E-04	1.60E-05	8.27E-05	0.00E+00	3.71E-03	1.48E-05	1.53E-06
	$GWP_{LU\&LUT}$(1)	kg CO_2 eq.	2.08E-02	5.94E-05	2.22E-04	2.79E-05	4.31E-04	0.00E+00	1.94E-02	1.83E-05	2.23E-06
	ADP-ff(2)	MJ, LHV	5.19E+01	1.38E+00	1.80E+00	8.20E-01	1.21E+00	0.00E+00	5.36E+01	1.88E+00	9.32E-02
	AP	kg SO_2 eq.	6.86E-03	6.14E-04	2.22E-04	1.29E-04	1.85E-04	0.00E+00	8.04E-03	7.23E-04	2.54E-05
	EP_f	kg P eq.	4.04E-04	8.79E-06	3.52E-05	4.33E-06	9.32E-06	0.00E+00	4.18E-04	2.55E-06	2.95E-07
	EP_m	kg N eq.	4.88E-03	6.26E-04	1.43E-04	9.65E-05	1.48E-04	0.00E+00	6.31E-03	8.83E-04	2.76E-05
	ODP	kg CFC-11 eq.	2.07E-06	1.66E-09	8.63E-10	9.97E-10	4.24E-08	0.00E+00	1.91E-06	2.40E-09	1.15E-10
	SFP	kg O_3 eq.	1.23E-01	1.60E-02	8.19E-03	2.72E-03	5.10E-03	2.39E-02	2.13E-01	2.41E-02	4.20E-02
Resource use	RPR_E(3)	MJ, LHV	1.59E+00	2.73E-02	3.18E-01	1.17E-02	4.01E-02	0.00E+00	1.80E+00	8.30E-03	9.03E-04
	RPR_M(4)	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RPR_T	MJ, LHV	1.59E+00	2.73E-02	3.18E-01	1.17E-02	4.01E-02	0.00E+00	1.80E+00	8.30E-03	9.03E-04
	$NRPR_E$(5)	MJ, LHV	2.16E+01	1.39E+00	2.14E+00	8.25E-01	5.98E-01	0.00E+00	2.61E+01	1.88E+00	9.36E-02
	$NRPR_M$(6)	MJ, LHV	3.13E+01	0.00E+00	0.00E+00	0.00E+00	6.39E-01	0.00E+00	2.88E+01	0.00E+00	0.00E+00
	$NRPR_T$	MJ, LHV	5.29E+01	1.39E+00	2.14E+00	8.25E-01	1.24E+00	0.00E+00	5.49E+01	1.88E+00	9.36E-02
	SM	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	NRSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	FW(7)	m³	1.51E-02	2.04E-04	8.40E-04	1.18E-04	3.39E-04	0.00E+00	1.52E-02	9.15E-05	9.89E-05
Output flows and waste categories	HWD(8)	kg	8.25E-01	4.74E-02	1.85E-01	2.36E-02	2.26E-02	0.00E+00	1.01E+00	1.36E-02	1.57E-03
	NHWD(9)	kg	1.40E-01	7.71E-02	1.25E-02	7.01E-02	2.86E-02	0.00E+00	9.93E-01	9.15E-03	6.19E-01
	HLRW(10)	m³	2.49E-09	2.00E-11	4.89E-10	9.73E-12	6.17E-11	0.00E+00	2.77E-09	7.54E-12	7.33E-13
	ILLRW(11)	m³	1.88E-08	1.06E-10	1.42E-09	5.11E-11	4.17E-10	0.00E+00	1.88E-08	3.85E-11	3.95E-12
	CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MFR	kg	0.00E+00	0.00E+00	1.86E-03	0.00E+00	3.79E-05	0.00E+00	1.71E-03	0.00E+00	0.00E+00
	MER	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	EE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Additional indicator – TRACI 2.1											
	EP	kg N eq.	5.22E-03	1.12E-04	2.97E-04	4.70E-05	1.19E-04	0.00E+00	5.31E-03	7.58E-05	4.35E-06

Table 20: Static facer results for polyiso roof insulation board with fiber glass reinforced cellulosic facer (GRF).

Environmental indicator		Unit	A1 (per m2)	A2 (per m2)	A3 (per m2)	A4 (per m2)	A5 (per m2)	B1 (per m2)	B4 (per m2)	C2 (per m2)	C4 (per m2)
IPCC AR5 and TRACI 2.2	GWP[1]	kg CO_2 eq.	9.73E-01	3.96E-02	6.40E-02	3.06E-02	7.65E-02	0.00E+00	1.16E+00	8.36E-02	2.28E-03
	GWP_{fossil}[1]	kg CO_2 eq.	9.13E-01	3.96E-02	6.39E-02	3.06E-02	7.51E-02	0.00E+00	1.10E+00	8.36E-02	2.28E-03
	$GWP_{biogenic}$[1]	kg CO_2 eq.	6.00E-02	1.21E-05	5.85E-05	9.08E-06	1.27E-03	0.00E+00	5.52E-02	8.49E-06	9.23E-07
	$GWP_{LU\&LUT}$[1]	kg CO_2 eq.	1.02E-04	2.50E-05	7.86E-05	1.58E-05	3.14E-05	0.00E+00	2.41E-04	1.05E-05	1.35E-06
	ADP-ff[2]	MJ, LHV	1.14E+01	5.32E-01	9.99E-01	4.65E-01	9.92E-01	0.00E+00	1.42E+01	1.08E+00	5.63E-02
	AP	kg SO_2 eq.	2.15E-03	3.77E-04	1.45E-04	7.34E-05	4.37E-04	0.00E+00	3.34E-03	4.15E-04	1.53E-05
	EP_f	kg P eq.	3.14E-04	3.18E-06	2.14E-05	2.46E-06	1.39E-05	0.00E+00	3.21E-04	1.47E-06	1.78E-07
	EP_m	kg N eq.	1.24E-03	3.45E-04	8.05E-05	5.48E-05	4.89E-04	0.00E+00	2.57E-03	5.08E-04	1.67E-05
	ODP	kg CFC-11 eq.	4.84E-09	6.52E-10	5.68E-10	5.65E-10	1.17E-09	0.00E+00	8.62E-09	1.38E-09	6.97E-11
	SFP	kg O_3 eq.	3.16E-02	8.71E-03	2.15E-03	1.54E-03	1.25E-02	0.00E+00	6.67E-02	1.38E-02	4.33E-04
Resource use	RPR_E[3]	MJ, LHV	8.90E-01	9.97E-03	7.35E-02	6.65E-03	4.65E-02	0.00E+00	9.30E-01	4.77E-03	5.45E-04
	RPR_M[4]	MJ, LHV	5.38E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-01	0.00E+00	4.94E+00	0.00E+00	0.00E+00
	RPR_T	MJ, LHV	6.27E+00	9.97E-03	7.35E-02	6.65E-03	1.56E-01	0.00E+00	5.87E+00	4.77E-03	5.45E-04
	$NRPR_E$[5]	MJ, LHV	1.69E+01	5.39E-01	1.24E+00	4.68E-01	1.13E+00	0.00E+00	1.95E+01	1.08E+00	5.65E-02
	$NRPR_M$[6]	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.75E-02	0.00E+00	2.47E-02	0.00E+00	0.00E+00
	$NRPR_T$	MJ, LHV	1.69E+01	5.39E-01	1.24E+00	4.68E-01	1.15E+00	0.00E+00	1.95E+01	1.08E+00	5.65E-02
	SM	kg	4.64E-01	0.00E+00	0.00E+00	0.00E+00	9.46E-03	0.00E+00	4.26E-01	0.00E+00	0.00E+00
	RSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	NRSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	FW[7]	m^3	4.49E-03	7.30E-05	3.64E-04	6.71E-05	3.35E-04	0.00E+00	4.92E-03	5.26E-05	5.97E-05
Output flows and waste categories	HWD[8]	kg	1.68E+00	1.71E-02	1.12E-01	1.34E-02	7.23E-02	0.00E+00	1.71E+00	7.81E-03	9.48E-04
	NHWD[9]	kg	1.21E-01	2.44E-02	9.54E-03	3.98E-02	1.84E-02	0.00E+00	6.12E-01	5.26E-03	3.74E-01
	HLRW[10]	m^3	2.89E-09	7.22E-12	2.08E-10	5.52E-12	1.03E-10	0.00E+00	2.89E-09	4.33E-12	4.43E-13
	ILLRW[11]	m^3	2.57E-08	3.84E-11	1.05E-09	2.90E-11	7.37E-10	0.00E+00	2.48E-08	2.21E-11	2.38E-12
	CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MFR	kg	0.00E+00	0.00E+00	2.97E-03	0.00E+00	6.06E-05	0.00E+00	2.73E-03	0.00E+00	0.00E+00
	MER	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	EE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Additional indicator – TRACI 2.1											
	EP	kg N eq.	2.86E-03	4.59E-05	1.78E-04	2.67E-05	1.56E-04	0.00E+00	2.99E-03	4.36E-05	2.63E-06

Table 21: Foam results for polyiso roof insulation boards without fiber glass reinforced cellulosic facer (GRF), with a thickness that gives an average thermal resistance RSI = 1 m²K/W.

	Environmental indicator	Unit	A1	A2	A3	A4	A5	B1	B4	C2	C4
			(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)	(per m2)
IPCC AR5 and TRACI 2.2	GWP(1)	kg CO_2 eq.	2.08E+00	6.89E-02	1.17E-01	5.30E-02	5.24E-02	0.00E+00	2.30E+00	1.43E-01	3.67E-03
	GWP_{fossil}(1)	kg CO_2 eq.	2.05E+00	6.89E-02	1.17E-01	5.30E-02	5.19E-02	0.00E+00	2.27E+00	1.43E-01	3.67E-03
	$GWP_{biogenic}$(1)	kg CO_2 eq.	3.79E-03	2.10E-05	1.04E-04	1.57E-05	8.08E-05	0.00E+00	3.63E-03	1.45E-05	1.49E-06
	$GWP_{LU\&LUT}$(1)	kg CO_2 eq.	2.03E-02	4.35E-05	1.37E-04	2.74E-05	4.19E-04	0.00E+00	1.89E-02	1.79E-05	2.18E-06
	ADP-ff(2)	MJ, LHV	5.17E+01	9.27E-01	1.73E+00	8.05E-01	1.19E+00	0.00E+00	5.28E+01	1.84E+00	9.07E-02
	AP	kg SO_2 eq.	6.77E-03	6.56E-04	2.52E-04	1.27E-04	1.85E-04	0.00E+00	8.00E-03	7.09E-04	2.47E-05
	EP_f	kg P eq.	3.94E-04	5.53E-06	3.71E-05	4.26E-06	9.10E-06	0.00E+00	4.08E-04	2.50E-06	2.87E-07
	EP_m	kg N eq.	4.82E-03	6.01E-04	1.40E-04	9.48E-05	1.47E-04	0.00E+00	6.21E-03	8.66E-04	2.69E-05
	ODP	kg CFC-11 eq.	2.26E-06	1.14E-09	9.85E-10	9.79E-10	4.62E-08	0.00E+00	2.08E-06	2.35E-09	1.12E-10
	SFP	kg O_3 eq.	1.22E-01	1.52E-02	8.76E-03	2.67E-03	5.20E-03	2.66E-02	2.16E-01	2.36E-02	4.67E-02
Resource use	RPR_E(3)	MJ, LHV	1.56E+00	1.74E-02	1.67E-01	1.15E-02	3.61E-02	0.00E+00	1.62E+00	8.14E-03	8.79E-04
	RPR_M(4)	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RPR_T	MJ, LHV	1.56E+00	1.74E-02	1.67E-01	1.15E-02	3.61E-02	0.00E+00	1.62E+00	8.14E-03	8.79E-04
	$NRPR_E$(5)	MJ, LHV	2.15E+01	9.38E-01	2.14E+00	8.11E-01	5.85E-01	0.00E+00	2.55E+01	1.84E+00	9.11E-02
	$NRPR_M$(6)	MJ, LHV	3.12E+01	0.00E+00	0.00E+00	0.00E+00	6.37E-01	0.00E+00	2.87E+01	0.00E+00	0.00E+00
	$NRPR_T$	MJ, LHV	5.27E+01	9.38E-01	2.14E+00	8.11E-01	1.22E+00	0.00E+00	5.42E+01	1.84E+00	9.11E-02
	SM	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	NRSF	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	FW(7)	m³	1.48E-02	1.27E-04	6.33E-04	1.16E-04	3.27E-04	0.00E+00	1.46E-02	8.97E-05	9.63E-05
Output flows and waste categories	HWD(8)	kg	8.02E-01	2.98E-02	1.94E-01	2.32E-02	2.19E-02	0.00E+00	9.80E-01	1.33E-02	1.53E-03
	NHWD(9)	kg	1.37E-01	4.26E-02	1.51E-02	6.89E-02	2.79E-02	0.00E+00	9.41E-01	8.97E-03	6.02E-01
	HLRW(10)	m³	2.45E-09	1.26E-11	3.60E-10	9.56E-12	5.82E-11	0.00E+00	2.62E-09	7.39E-12	7.14E-13
	ILLRW(11)	m³	1.85E-08	6.69E-11	1.82E-09	5.02E-11	4.19E-10	0.00E+00	1.88E-08	3.77E-11	3.84E-12
	CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MFR	kg	0.00E+00	0.00E+00	4.46E-03	0.00E+00	9.11E-05	0.00E+00	4.10E-03	0.00E+00	0.00E+00
	MER	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	EE	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Additional indicator – TRACI 2.1											
	EP	kg N eq.	5.10E-03	8.00E-05	3.09E-04	4.62E-05	1.16E-04	0.00E+00	5.17E-03	7.43E-05	4.24E-06

6.4. BENCHMARKING AGAINST THE INDUSTRY-WIDE AVERAGE RESULTS

Johns Manville product-specific EPDs were prepared with the same model as the PIMA industry-average EPDs;[10] hence, results may be compared. The difference between results is calculated as follows:

$$Differnce\ (\%) = \frac{\left(JM's_{\ product-specific} - PIMA_{\ industry-average}\right)}{PIMA_{\ industry-average}} * 100\%$$

For example, for Johns Manville's polyiso roof insulation board with coated glass facer global warming potential (GWP) results compared to PIMA's polyiso roof insulation board at 20 psi with coated glass facer global warming potential (GWP) result, the different is -1.3%:

$$Differnce\ (\%) = \frac{(4.41 - 4.46)}{4.46} * 100\% = -1.3\%$$

Table 22: Johns Manville (JM) polyiso roof insulation boards product-specific global warming potential (GWP) A1-A3 results compared to PIMA industry-average results.

Product	Unit	PIMA Industry-average A1-A3		JM's product-specific	Difference	
		20 psi (per m2)	25 psi (per m2)	(per m2)	20 psi %	25 psi %
Roof - CGF	kg CO_2 eq.	4.46E+00	4.44E+00	4.41E+00	**-1.3%**	**-1.3%**
Roof - GRF	kg CO_2 eq.	3.42E+00	3.53E+00	3.34E+00	**-2.4%**	**-5.4%**

6.5. FURTHER INFORMATION

Additional information is available on Johns Manville website: https://www.jm.com/en/industrial-insulation/polyisocyanurate-insulation/.

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