POLYISOCYANURATE INSULATION MANUFACTURERS ASSOCIATION

ENVIRONMENTAL PRODUCT DECLARATION

Polyiso High-Density Roof Cover 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 30, 2020
Period of Validity: 5 years
Declaration Number: EPD10467

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

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

Holcim
26 Century Blvd., Suite 205
Nashville, TN 37214
www.holcimbe.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

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

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

Carlisle SynTec
1285 Ritner Highway
Carlisle, PA 17013
www.carlislesyntec.com

CertainTeed Corporation
20 Moores Road
Malvern, PA 19355
www.certainteed.com

Duro-Last, Inc.
525 Morley Drive
Saginaw, MI 48601
www.duro-last.com

FiberTite/Seaman Corporation
1000 Venture Blvd.
Wooster, OH 44691
www.fibertite.com

Flex Membrane International Corp.
2670 Leiscz's Bridge Road, Suite 400
Leesport, PA 19533
www.flexroofingsystems.com

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

Mule-Hide Products Co., Inc.
1195 Prince Hall Drive
Beloit, WI 53511
www.mulehide.com

Sika Sarnafil
100 Dan Road
Canton, MA 02021
usa.sika.com/sarnafil

Siplast
1000 Rochelle Blvd.
Irving, TX 75062
www.siplast.com

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

Versico Roofing Systems
1285 Ritner Highway
Carlisle, PA 17013
www.versico.com

WeatherBond Roofing
P.O. Box 251
Plainfield, PA 17081
www.weatherbondroofing.com

Wise Product Group
3812 E. 91st Street
Cleveland, OH 44105
www.garlandco.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)
Refereerence PCRs	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	EPD10467
Product	Polyisocyanurate High-Density (HD) Roof Cover Boards
Intended Applications and Use	Commercial, light commercial, residential and industrial roof construction
Markets of Applicability	United States and Canada
Product RSL Description	40 years
Declared Product & Function Unit	1 m^2 of installed insulation material with a thickness that gives an average thermal resistance R_{SI} = 1 $m^2 \cdot K/W$ (5.678 $ft^2 \cdot °F \cdot h/Btu$) 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 30, 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 33 polyiso manufacturing facilities in the United States and Canada. Each facility's annual electricity use, natural gas use, water use and wastewater, product packaging, 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 HD roof cover boards.

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 HD roof cover boards during their life cycle.

LIFE CYCLE ASSESSMENT SCOPE AND BOUNDARIES

System Boundary: Cradle-to-Grave.

This declaration is a 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 HD roof cover boards.
- **Transport of raw materials (A2):** Transport of materials (all chemical and material inputs including packaging) to polyiso HD roof cover boards manufacturing facilities.
- **Manufacturing of products (A3):** Production of polyiso HD roof cover boards (including associated emissions from production facilities).

Construction Stage

- **Transport from gate to site (A4):** Transport of polyiso HD roof cover boards in bundles from the manufacturing facilities to product distributor sites or directly to project job sites.
- **Assembly/Install (A5):** Installation of polyiso HD roof cover 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 HD roof cover 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):** Upon installation the product remains in place in the roof assembly and provides resistance to transfer of energy in and out of the building. There is no activity associated during the use of polyiso HD roof cover boards.

- **Maintenance (B2):** Polyiso HD roof cover boards are installed permanently within a weather protected exterior building envelope and therefore 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 HD roof cover 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 one replacement is required.
- **Refurbishment (B5):** Polyiso HD roof cover 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 HD roof cover boards 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 HD roof cover boards are removed from the roof deck. Although, the polyiso HD roof cover boards may be recovered from the roof system and reused, this activity is not considered in this study.
- **Transport (C2)**: Transport of polyiso HD roof cover boards to a landfill.
- **Waste Processing (C3):** Polyiso HD roof cover boards do not require waste processing.
- **Disposal (C4):** Disposal of polyiso HD roof cover boards in a landfill.

Geographic Coverage: Polyiso HD roof cover boards manufactured in the United States and Canada.

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 roof cover board 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. Polyiso HD roof cover 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. The facer is comprised of polymer-bonded coated glass facer (CGF) and it plays a critical role in accommodating a continuous manufacturing process.

Features and Benefits

The versatile, durable and sustainable polyiso HD roof cover boards offer the following benefits:

- Excellent impact resistance from foot traffic, storms and hail
- Long-term durability
- Superior water resistance
- Lightweight for installation efficiencies
- Easy to cut (no special tools required) and virtually dust free
- Resistance to mold growth

Image 1.
Polyiso HD Roof Cover Board.

APPLICATION

Polyiso HD roof cover boards may be used in commercial, light commercial, residential, and industrial roof construction projects on new buildings and on existing buildings during reroofing, and provide added rigidity, strength and impact resistance. These products are versatile and compatible with single-ply roof membrane systems (i.e., TPO, PVC and EPDM) and modified bitumen (self-adhered and cold-applied) roof membrane systems. The polyiso HD roof cover boards are also compatible with various insulation types. These products are installed in roof systems between the insulation (below) and roof membrane (above) and may be mechanically attached or adhered. A typical roof system that includes a polyiso HD roof cover board is illustrated in Figure 1. Many factors and design consideration impact the selection of a roof system and additional components, such as air barrier, vapor retarder and thermal barrier, may be required in specific applications.

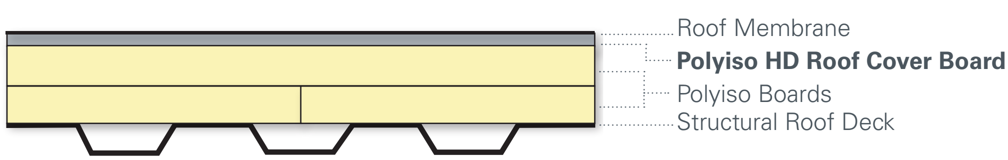

Figure 1.
Typical Roof Assembly with Polyiso HD Roof Cover Board Installed Between the Insulation and the Roof Membrane.

TECHNICAL REQUIREMENTS

Polyiso HD roof cover boards are manufactured to meet the requirements of industry consensus product specifications and standards in the United States and Canada. 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 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: 072200 Roof and Deck Insulation.

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

PHYSICAL PROPERTY	STANDARD DESIGNATION	ASTM C1289 (TYPE II, CLASS 4)	CAN/ULC S704.1 (TYPE 4, 5 & 6)
Thermal Resistance (R-value or long-term thermal resistance), °F·ft²·h/Btu (K·m²/W), min	→	For 0.25-inch (6.4 mm): 1.0 (0.18) For 0.5-inch (12.7 mm): 2.0 (0.35) measured per ASTM C518 at 75°F (24°C) after 180 conditioning period	For 0.25-inch (6.35 mm): 1.0 (0.18) For 0.5-inch (12.5 mm): 2.0 (0.4) measured per CAN/ULC-S770 long-term thermal resistance
Compressive Strength, psi (kPa), min	ASTM D1621	Grade 1: 80 (551) Grade 2: 110 (758) Grade 3: 140 (965)	Type 4: 80 (550) Type 5: 100 (760) Type 6: 140 (965)
Flexural Strength, psi (kPa), min	ASTM C203	400 (2750) for 12 mm (1/2-inch) product 800 (5500) for 6 mm (1/4 inch) product	400 (2750)
Tensile Strength, psf (kPa), min	→	2000 (95) measured per ASTM C209	2000 (95) 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: 4.5 200°F (93°C) / ambient RH: 4.0	Not Applicable
Dimensional Stability, % Linear Change, Length and Width, max	ASTM D2126	-40°F (-40°C) / ambient RH: 1.0 158°F (70°C) / 97% RH: 1.0 200°F (93°C) / ambient RH: 1.0	-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	→	4.0 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	≤1.5 (≤85.5)	Class 1: ≤0.26 (≤15) Class 2: ≥0.26, ≤1.05 (≥15, ≤60) Class 3: > 1.05 (>60)

Thermal Performance: The recognized consensus approach for determining the thermal resistance of permeably-faced closed-cell foam insulation with captive blowing agents such as polyiso relies on the concept of Long-Term Thermal Resistance (LTTR) as described in CAN/ULC-S770 "Standard Test Method for Determination of Long-Term Thermal Resistance of Closed-Cell Thermal Insulating Foams" and ASTM C1303/C1303M "Standard Test Method for Predicting Long-Term Thermal Resistance of Closed-Cell Foam Insulation." LTTR provides a laboratory method of accelerating the aging of closed-cell thermal insulation products with captive blowing agents to estimate the long-term aged thermal resistance. This approach is based on a scientific theory of aging plastic foams with captive blowing agents developed in the 1990s and a robust evaluation of the methodology spearheaded by Oak Ridge National Laboratory (Stovall T., et. al., 2012). The polyiso industry has adopted the LTTR methodology for quantifying thermal resistance of permeably-faced polyiso roof insulation boards. Additional information regarding LTTR methodology is available on the PIMA website *(www.polyiso.org)*.

PROPERTIES OF DECLARED PRODUCT AS DELIVERED

The manufactured and cured polyiso HD roof cover 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). Typically, the bundles are comprised of 42 to 96 boards.

MATERIAL COMPOSITION

Polyiso HD roof cover boards are comprised of a foam core and 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 followed by a curing process. The coated polymer-bonded glass fiber facer (CGF) is composed of a glass fiber mat with inorganic polymer coatings.

Table 2.
Weighted Average Foam Formulation
for Polyiso HD Roof Cover Boards.

COMPONENT	FORMULATION RANGE (% BY MASS)
MDI	60.3
Polyester Polyol	30.1
Blowing Agent (Pentane)	3.3
Flame Retardant (TCPP)	4.0
Surfactant	0.6
Catalyst	1.6
Water	0.1

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

MANUFACTURING

This module includes manufacturing of polyiso HD roof cover 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 catalyst, surfactant, and flame retardant) 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 lift to a warehouse area for storage and eventual loading onto trucks for shipment. The manufacturing process for polyiso HD roof cover boards at a typical manufacturing plant is illustrated in Figure 2. Bundles of polyiso HD roof cover 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.*

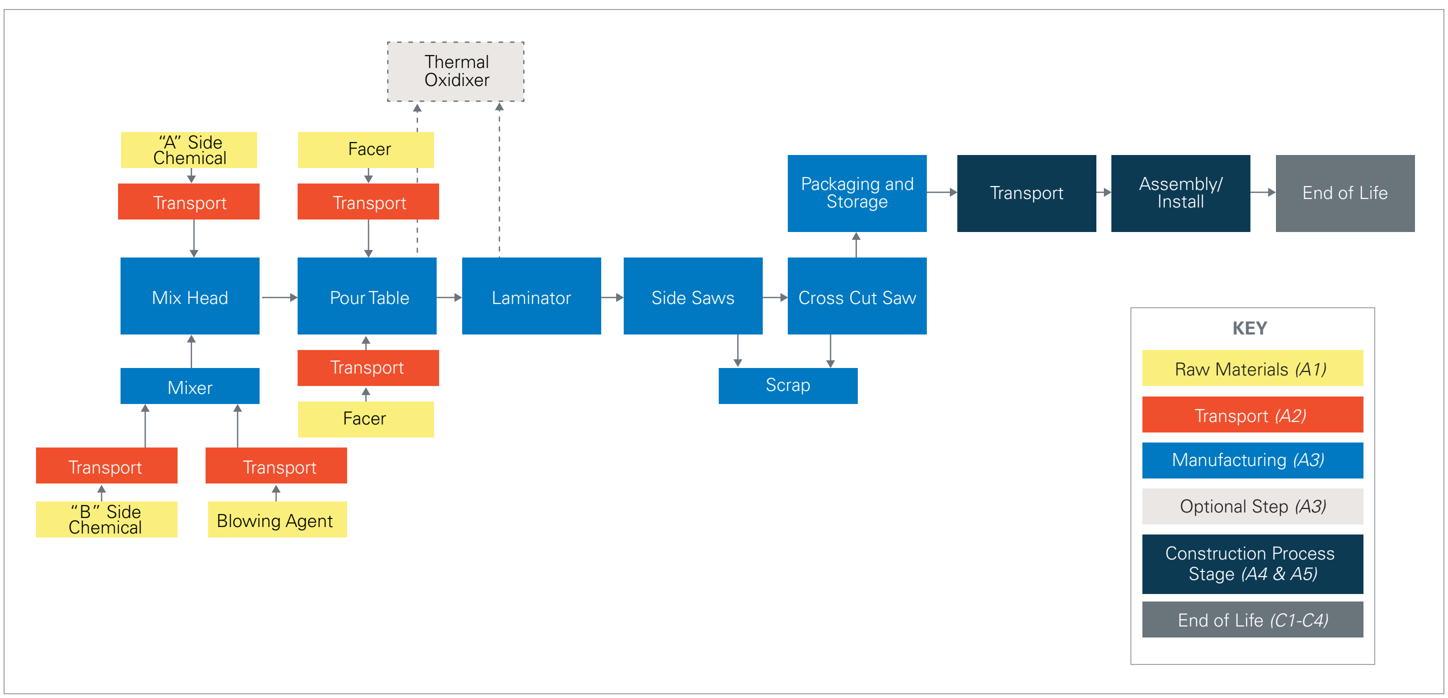

Figure 2.
Process Flow Diagram for Polyiso HD Roof Cover Boards.
(Note: Currently 44% of participating polyiso manufacturing facilities operate with thermal oxidizers for emissions control of pentane.)

TRANSPORTATION

The polyiso HD roof cover 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 642 km (399 miles). Additional transportation details are reported in Table 3.

PRODUCT INSTALLATION

Upon delivery to the jobsite, the bundles of polyiso HD roof cover boards are unloaded from the truck to the rooftop using a crane or all terrain forklift, all packaging is removed, and the individual boards are placed on the roof deck by a roofing crew. The boards are secured to the insulation or 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 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 HD roof cover boards. In a roofing system, the cover board is located on top of roof insulation and below the roof membrane. The polyiso HD roof cover boards provide added rigidity, strength and impact resistance. The roof membrane when installed properly and adequately maintained, protects the polyiso HD roof cover boards from environmental elements and weather during its use. Therefore, it is expected that cover boards 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. 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 cover boards will serve its functional purpose for the 75-year life span of the building. However, 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.

Roof replacement 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 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. Although the Roof Recover approach is a common practice and allows the service life of a roof system to be extended, it is often not captured in reroofing studies available in the public domain, which typically contemplate 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 establishes a 40-year RSL for polyiso HD roof cover boards. 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.

Therefore, this study conservatively assumes all polyiso HD roof cover boards are disposed in the landfill during Roof Replacement. Therefore, the polyiso HD roof cover boards' cradle-to-grave assessment incorporates all life cycle stage environmental impacts connected with the original building construction with a Roof Recover operation at 20-years as well as the building's Roof Replacement operation at 40-years. This translates to 1.9 replacement cycles during the 75-year building ESL (75-year ESL/40-year RSL = 1.9 replacement cycle).

END OF LIFE

At the end of building service life and during roof replacement, the polyiso HD roof cover 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 insulation is removed when the building Pavlovich, et. al., is decommissioned and disposed 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 this 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 judgment 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 production of polyester polyol, CGF facers, and polyiso HD roof cover 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 were 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 HD roof cover boards. Additional information regarding time, geographic and technology coverage is provided below:

TIME COVERAGE: The data represents production of polyester polyols, CGF facers, and polyiso HD roof cover boards during the 2017 calendar year.

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

TECHNOLOGY COVERAGE: The process technology modeled is based on polyiso manufacturers, polyester polyol manufacturers, and facer manufacturers representing production in the United States and Canada. Primary data was collected for production of polyester polyols, CGF facers, and manufacturing of polyiso HD roof cover 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, CGF facers, and polyiso HD roof cover boards during the 2017 calendar year.

ESTIMATES AND ASSUMPTIONS

The material and energy inputs for production of polyiso HD roof cover boards were modeled with data collected from the 33 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; 1 kg 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 roofs 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 HD roof cover boards 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*	642	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 market for 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	µg/m3
Product loss per functional unit	1	%
Output materials resulting from on-site waste processing, generated by packaging waste (assumed landfilled)	0.00142	kg
Waste materials at the construction site before waste processing, generated by product installation (assumed landfilled)	0.0269	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	40	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
Replacement Cycle	1	Number/RSL
Replacement Cycle	1.9	Number/ESL

Table 7.
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 $m^2 \cdot K/W$ 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 ($ft^2 \cdot °F \cdot h/Btu$) with 1 $m^2 \cdot K/W$ equivalent to (5.678 $ft^2 \cdot °F \cdot h/Btu$). The data for a 0.013 m (0.5-inch) thick, polyiso HD roof over boards with 0.4 $m^2 \cdot K/W$ (2.5 $ft^2 \cdot °F \cdot h/Btu$) R-value is normalized to a thermal resistance of 1 $m^2 \cdot K/W$ (5.678 $ft^2 \cdot °F \cdot h/Btu$). Table 8 provides the characteristics of the functional unit.

Table 8.
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 $m^2 \cdot K/W$ (5.678 ft2·°F·h/Btu)	
Mass	2.69 (5.93)	kg (lb)
Thickness to achieve functional unit	0.0288 (1.13)	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, B5, B6, B7, C1 and C3 do not contribute to impacts 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 9.
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 polyiso HD roof cover board by functional unit RSI=1 m2·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.

Product: Polyiso HD Roof Cover Boards.

Table 10.
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	2.17E+01
ODP: Ozone Depletion Potential	kg CFC-11 eq	1.59E-06
AP: Acidification Potential	kg SO_2 eq	1.01E-01
EP: Eutrophication Potential	kg N eq	1.49E-01
POCP: Photochemical Oxidant Creation Potential	kg O_3 eq	1.27E-00
ADP_{fossil}: Abiotic Resource Depletion Potential of Non-renewable energy resources	MJ, LHV	4.10E+01

Table 11.
TRACI 2.1 Impact Categories – Functional Unit by System Boundary Module.

IMPACT CATEGORY	UNIT	A1	A2	A3	A4	A5	B4	C2	C4
GWP	kg CO_2 eq	1.03E+01	1.64E-01	2.14E-01	2.55E-01	1.41E-01	1.03E+01	1.39E-02	3.41E-01
ODP	kg CFC-11 eq	7.14E-07	3.49E-08	1.55E-08	6.34E-08	2.68E-10	7.53E-07	3.47E-09	6.11E-09
AP	kg SO_2 eq	4.79E-02	1.50E-03	3.65E-04	1.31E-03	1.86E-03	4.81E-02	7.16E-05	4.06E-04
EP	kg N eq	2.72E-02	2.99E-04	1.13E-03	3.06E-04	1.44E-04	7.04E-02	1.67E-05	4.91E-02
POCP	kg O_3 eq	5.18E-01	4.06E-02	7.43E-03	3.29E-02	6.02E-02	6.03E-01	1.80E-03	9.92E-03
ADP_{fossil}	MJ, LHV	2.01E+01	3.15E-01	1.82E-01	5.71E-01	2.86E-01	1.94E+01	3.12E-02	8.87E-02

Table 12.
Resource Use Indicators – Functional Unit by System Boundary Module.

RESOURCE INDICATOR	UNIT	A1	A2	A3	A4	A5	B4	C2	C4
RPRE	MJ, LHV	6.92E+00	4.86E-02	9.49E-02	4.11E-02	4.36E-03	6.42E+00	2.25E-03	1.64E-02
RPRM	MJ, LHV	9.23E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.30E-01	0.00E+00	0.00E+00
NRPRE	MJ, LHV	1.41E+02	2.35E+00	2.08E+00	4.00E+00	1.93E+00	1.37E+02	2.19E-01	7.15E-01
NRPRM	MJ, LHV	4.81E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.33E+01	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	0.00E+00
FW	m^3	5.53E-02	5.13E-04	5.74E-04	6.73E-04	1.76E-04	5.23E-02	3.68E-05	8.62E-04
RSF	MJ	N/A	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	N/A
RE	MJ	N/A	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 (fuel); NRPRE: Non-renewable primary resources used as an energy carrier (fuel); NRPRM: Non-renewable primary resources used as an energy carrier (fuel); SM: Secondary materials; FW: Use of net fresh water resources.								
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 13.
Waste and Other Outputs – Functional Unit by System Boundary Module.

OUTPUT FLOWS	UNIT	A1	A2	A3	A4	A5	B4	C2	C4
HWD	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.52E-06	0.00E+00	8.36E-06
NHWD	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.31E-02	0.00E+00	2.57E-02
MR	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.24E-04	0.00E+00	3.60E-04
HLRW	kg	N/A	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	N/A
CRU	kg	N/A	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	N/A
EE	MJ	N/A	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 HD roof cover boards. As described in the Use and Reference Service Life section of this declaration, all life cycle stage environmental impacts are connected with the original building construction with "Roof Recover" operation at 20-years as well as the building's "Roof Replacement" operation at 40-years. This translates to 1.9 replacement cycles during the 75-year building ESL. The impact of the Roof Replacement operation is captured in module B4. The environmental profile for the initial 40-years for polyiso HD roof cover boards is captured in modules A1 through A5, C2 and C4. This distinction allows a closer examination of the impacts that the individual modules have on the overall environmental profile of polyiso HD roof cover boards.

When assessing environmental profiles of products, Global Warming Potential (GWP) is an important Impact Category. The relative impact of modules on GWP for polyiso HD roof cover boards is illustrated in Figure 3. Module A1 (raw materials) is the most dominant module accounting for (90%) of the impacts. The remaining modules A2, A3, A4, A5, C2 and C4, each contribute 3% or less to the impacts.

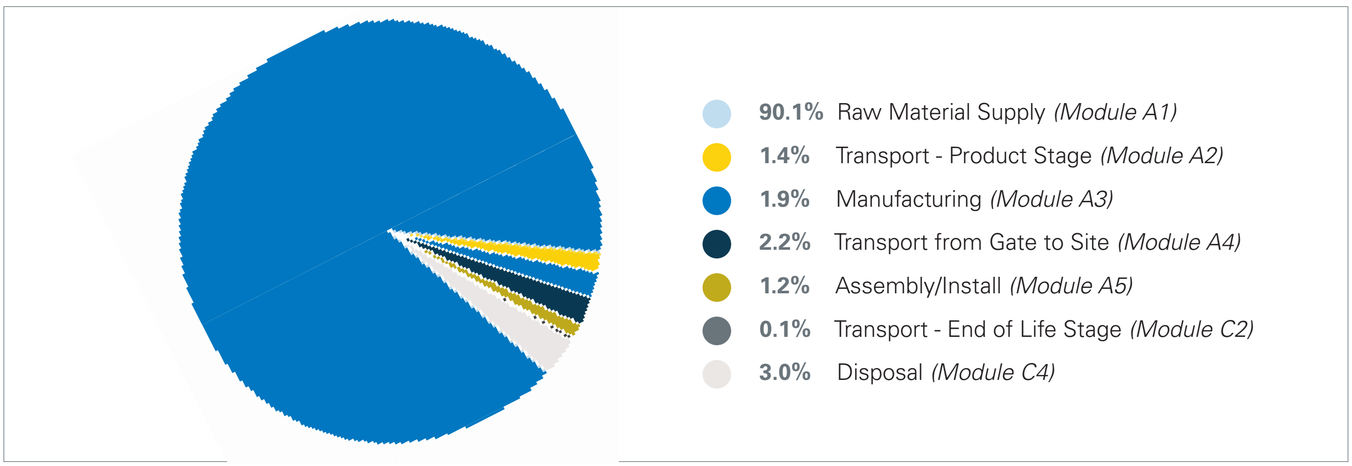

Figure 3.
Relative Impact of Modules on Global Warming Potential for Polyiso HD Roof Cover Boards.

The analysis in Tables 10 through 13 indicates that Module A1 (raw materials) dominates the environmental profile of polyiso HD roof cover boards. The aggregated primary and secondary data indicate that extraction and processing of raw materials have the largest impact. The polyiso industry is characterized as having a large number of plants that produce polyiso HD roof cover boards located throughout the Unites States and Canada. Many plants are located near large population centers with significant roof replacement and new roof construction activity, thus reducing the impacts from transportation.

Environmental Profiles for Common Polyiso Thicknesses

For this declaration, cradle-to-grave environmental profiles for polyiso HD roof cover board were calculated on the most common thicknesses: 0.013 m (0.5-inch) with R-value of 0.4 m2·K/W (2.5 ft2·°F·h/Btu). To provide the users of this document the opportunity to assess polyiso HD roof cover boards, the impacts and environmental indicator metrics are listed in Table 14 for all life cycle stages.

Table 14.
Impacts/Indicators for All Life Cycle Stages for Polyiso HD Roof Cover Boards.

IMPACT CATEGORY / ENVIRONMENTAL INDICATOR		UNIT	0.013 M (0.5-INCH) THICK RSI-0.4 M2·K/W (RIP-2.5 FT2·°F·H/BTU)	
			Per 1 ft^2	Per 1 m^2
TRACI 2.1 IMPACT CATEGORIES	**GWP: Global Warming Potential**	kg CO_2 eq	8.89E-01	9.75E+00
	ODP: Ozone Depletion Potential	kg CFC-11 eq	6.51E-08	7.07E-07
	AP: Acidification Potential	kg SO_2 eq	4.15E-03	4.47E-02
	EP: Eutrophication Potential	kg N eq	6.08E-03	6.54E-02
	POCP: Photochemical Oxidant Creation Potential	kg O_3 eq	5.21E-02	5.61E-01
	ADP_{fossil}: Abiotic Resource Depletion Potential of Non-Renewable Energy Resources	MJ, LHV	1.68E+00	1.80E+01
RESOURCE USE INDICATORS	**RPR_E: Renewable Primary Resources Used as an Energy Carrier (Fuel)**	MJ, LHV	5.54E-01	5.96E+00
	RPR_M: Renewable Primary Resources with Energy Content Used as Material	MJ, LHV	7.17E-01	7.72E+00
	$NRPR_E$: Non-Renewable Primary Resources Used as an Energy Carrier (Fuel)	MJ, LHV	1.19E+01	1.28E+02
	$NRPR_M$: Non-Renewable Primary Resources Used as Material	MJ, LHV	3.71E+00	3.99E+01
	PED: Total Primary Energy Demand	MJ, LHV	1.62E+01	1.74E+02
	SM: Secondary Materials	kg	0.00E+00	0.00E+00
	FW: Use of Net Fresh Water Resources	m^3	4.52E-03	4.87E-02
WASTE OUTPUT	**HWD: Hazardous Waste Disposed**	kg	6.50E-07	6.99E-06
	NHWD: Non-Hazardous Waste Disposed	kg	2.00E-03	2.15E-02
	MR: Materials for Recycle	kg	2.80E-05	3.01E-04

ADDITIONAL ENVIRONMENTAL INFORMATION

Fire Performance: The fire performance of low-slope roof assemblies is evaluated on assembly tests (from the deck to roof covering) with respect to both external and internal fire exposure. The fire exposures in tests simulates 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 noncombustible 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 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 Noncombustible 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.

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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.
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