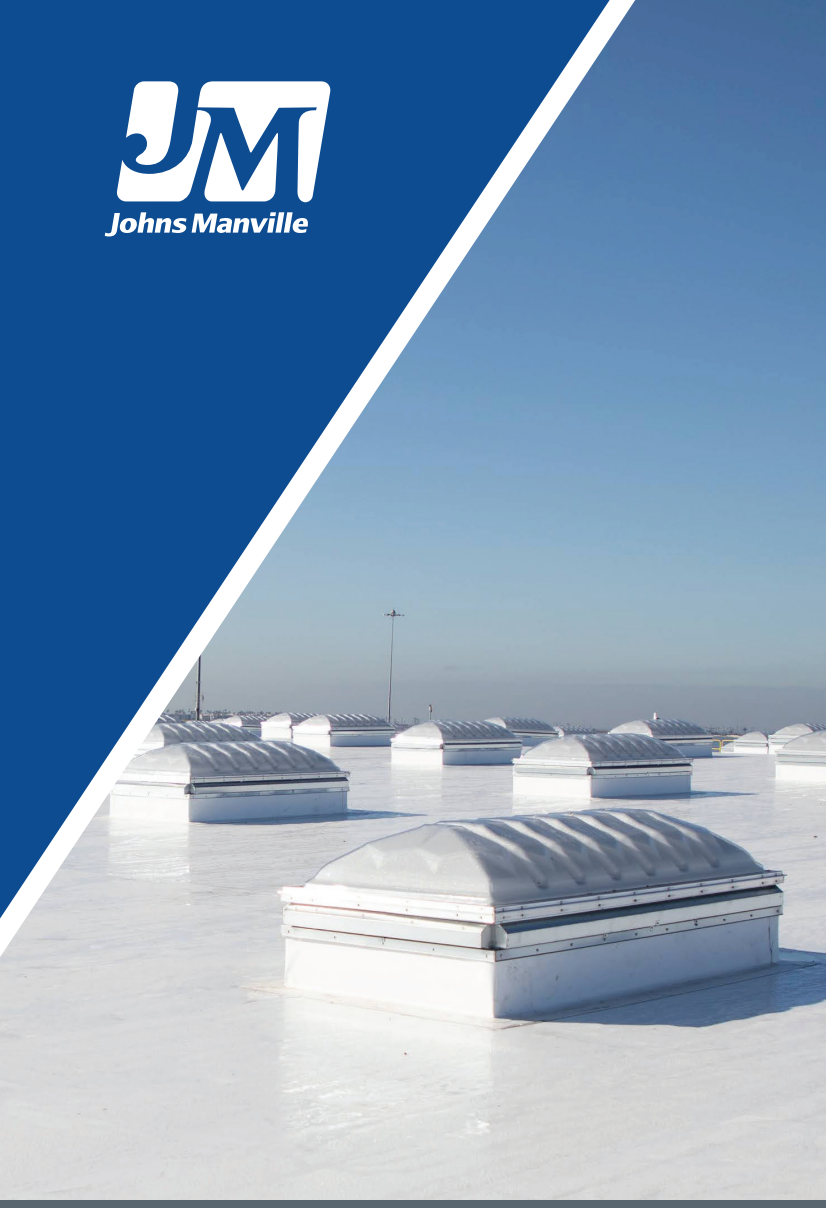
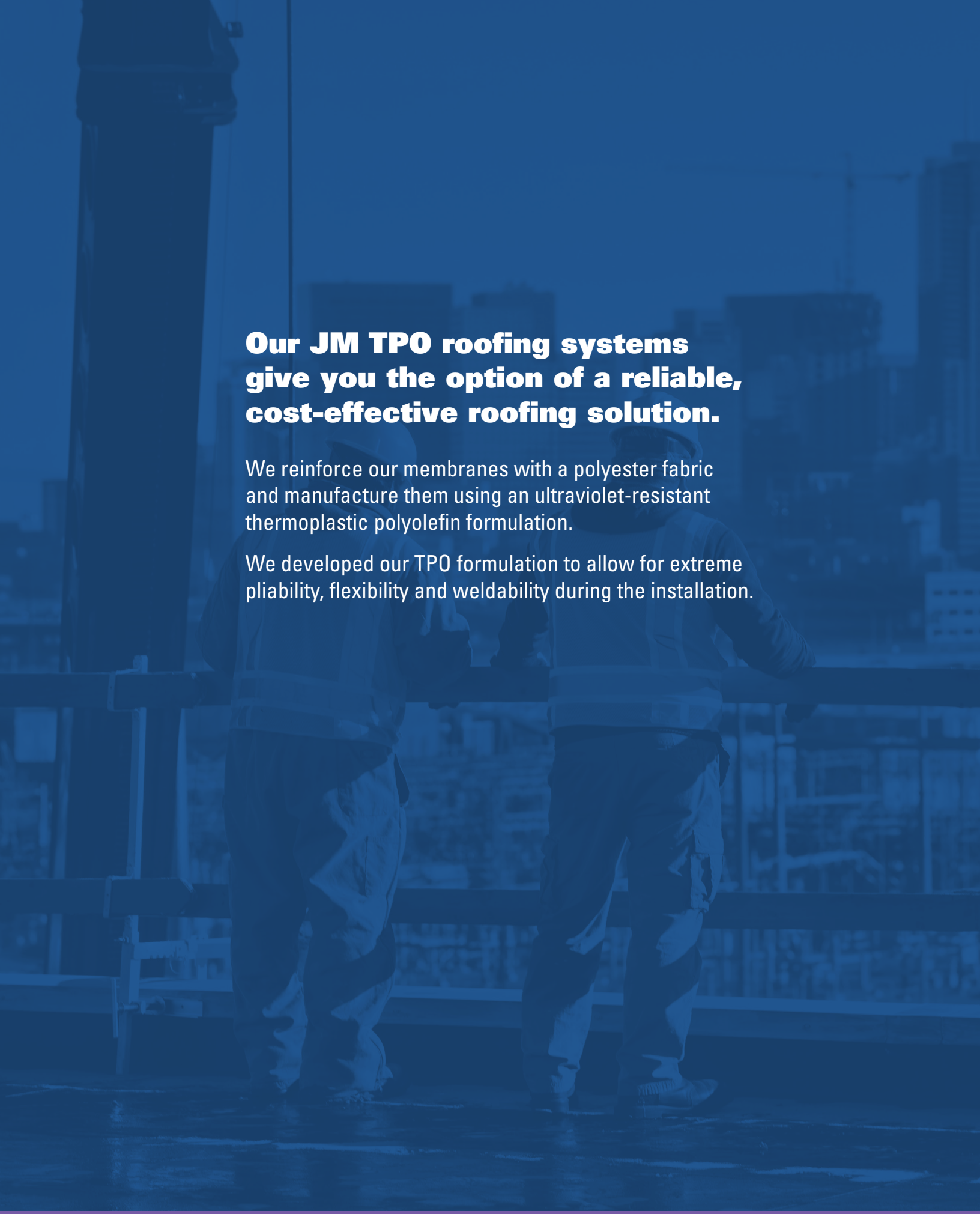
Johns Manville



JM TPO MEMBRANE

Environmental Product Declaration

JM TPO Roofing Membrane



Our JM TPO roofing systems give you the option of a reliable, cost-effective roofing solution.

We reinforce our membranes with a polyester fabric and manufacture them using an ultraviolet-resistant thermoplastic polyolefin formulation.

We developed our TPO formulation to allow for extreme pliability, flexibility and weldability during the installation.

An Industry Leader

Johns Manville, a Berkshire Hathaway company (NYSE: BRK.A, BRK.B), is a leading manufacturer and marketer of premium-quality products for building insulation, mechanical insulation, commercial roofing and roof insulation, as well as reinforcement fiberglass and technical nonwovens. JM serves markets that include aerospace, automotive and transportation, air handling, appliance, HVAC, pipe and equipment, air and liquid filtration, waterproofing, building, flooring, interiors and wind energy. In business since 1858, the Denver-based company has annual sales over $4 billion and holds leadership positions in all the key markets that it serves. Johns Manville employs 8,000 people and operates 44 manufacturing facilities in North America and Europe.

As a full-line roofing manufacturer of both single-ply and bituminous membrane systems, Johns Manville manufactures the following:

Thermoplastic Polyolefin membrane (TPO)
Ethylene Propylene Diene Monomer membrane (EPDM)
Polyvinyl Chloride membrane (PVC)
Styrene Butadiene Styrene (SBS)
Atactic Polypropylene (APP)
Built Up Roofing (BUR)
Polyisocyanurate Roof Insulation (ISO)

JM Sustainability Goals

At JM, we are passionate about our ability to succeed in making the company more sustainable. We know that by doing good, we will do well. That is why we've embraced sustainability, working to define what it means to JM and how it benefits our stakeholders. We realize that through these efforts to become more sustainable, we will become more resilient, more innovative, and better positioned to continue serving the changing needs of our customers.



REDUCE our impact on the planet. By 2025, we will:

- Reduce our waste intensity from our 2020 performance by 10%.
- We will use at least 2 billion pounds of external recycle materials in JM products from 2021 through 2025.

EXPAND support of our global workforce.

- Reflect our communities by attracting, promoting and retaining underrepresented groups resulting in an organization that is reflective of the communities where we operate.
- Inspire our employees to volunteer and actively engage in our communities.

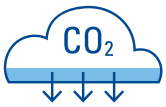
INNOVATE a path to a decarbonized future. We will:

- Develop and sell products that increase the net positive benefit to our world by more than 10% by 2025.
- Chart our path to a lower carbon future by:
  - Exploring and implementing alternative renewable energy sources used directly in JM processes
  - Developing a more complete understanding of the impact of our raw material supply chain as the use of fossil fuels phases out
  - Reducing our overall Scope 1&2 GHG emissions by 40% by 2030.

JM Sustainability Highlights *Through 2023*

Guided by our values and commitment to Building a Better Tomorrow, we have generated sustainable outcomes that benefit our planet, communities and customers.

CO_2 REDUCTION



-10%

JM recorded a 10% reduction from our baseline 2017 year as we work towards our 2030 goal of a 40% reduction in Scope 1 & 2 GHG emissions.

WASTE INTENSITY REDUCTION

-12%+

2023 reduction, exceeding our goal of 10% reduction by 2025.

JM Engineered Products (EP) has **12 straight quarters** of reducing waste intensity in progress to our target goal.

EXTERNAL RECYCLED MATERIAL

2 Billion+ lbs

JM is outpacing our 2025 goal of using 2 billion pounds of external recycled material use in products by **1.6% through 2023** – despite a tightening supply of recycled materials.

VOLUNTEER HOURS

completed by JM employees in 2023

4,000+

REDUCTION IN DAYS AWAY FROM WORK

due to workplace injuries & illnesses from 2020-2023

-47%

REDUCTION IN TOTAL CASE INCIDENT RATE

-4%+

vs. 2020 base year

JM continues working toward our goal of zero serious injuries.

BELOW THE INDUSTRY AVERAGE TOTAL CASE INCIDENT RATE

-61%

2023 rate vs. latest available industry average rate (2022).

DONATIONS BY JM EMPLOYEES

$357,000+

Donations for charitable and community impact efforts, including matching donation in 2023.

PRODUCTS CONTRIBUTING TO LEED CREDITS

72

CERTIFICATIONS

SILVER 2023 ecovadis Sustainability Rating

ENERGY STAR

US EPA Certified SmartWay®

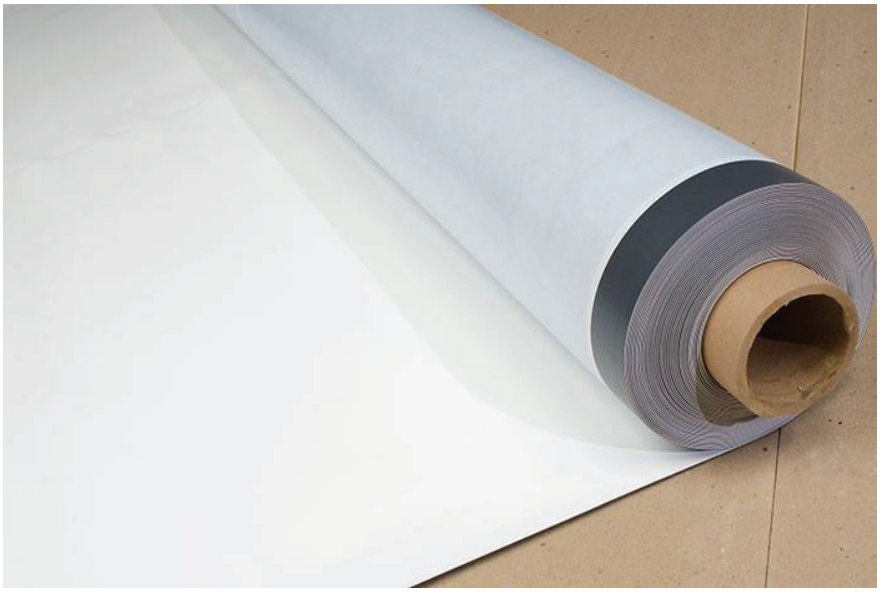
UL ECOLOGO

CERTIFIED INDOOR AIR QUALITY SCS GLOBAL SERVICES

ENVIRONMENTAL PRODUCT DECLARATION

TPO SINGLE-PLY ROOFING MEMBRANE

JOHNS MANVILLE



Think JM.

Johns Manville
A Berkshire Hathaway Company

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.

People ● Passion ● Perform ● Protect

UL CERTIFIED
ENVIRONMENTAL PRODUCT DECLARATION
UL.COM/EPD

EPD PROGRAM AND PROGRAM OPERATOR NAME, ADDRESS, LOGO, AND WEBSITE	UL Solutions 333 Pfingsten Rd, Northbrook IL, 60062 www.ul.com www.spot.ul.com
GENERAL PROGRAM INSTRUCTIONS AND VERSION NUMBER	Program Operator Rules v 2.7 2022
MANUFACTURER NAME AND ADDRESS	Johns Manville 117 Lequire Dr, Scottboro, AL 35768
DECLARATION NUMBER	4791137694.101.1
DECLARED PRODUCT & FUNCTIONAL UNIT OR DECLARED UNIT	1 m^2 of single-ply roofing membrane
REFERENCE PCR AND VERSION NUMBER	Part A: Product Category Rules for Building-Related Products and Services, UL 10010, v3.2 Part B: Product Category Rules for Single Ply Roofing Membranes, NSF International, v2
DESCRIPTION OF PRODUCT APPLICATION/USE	Single ply TPO roofing membrane installed and representative of 45, 60 and 80 mil thicknesses are used as a roofing protective layer for building applications.
PRODUCT RSL DESCRIPTION (IF APPL.)	N/A
MARKETS OF APPLICABILITY	North America
DATE OF ISSUE	February 24, 2025
PERIOD OF VALIDITY	5 Years
EPD TYPE	Product specific
RANGE OF DATASET VARIABILITY	N/A
EPD SCOPE	Cradle to gate with options (C1-C4)
YEAR(S) OF REPORTED PRIMARY DATA	Calendar year 2019
LCA SOFTWARE & VERSION NUMBER	Sphera LCA For Experts v10.9
LCI DATABASE(S) & VERSION NUMBER	Sphera MLC 2024.2 databases
LCIA METHODOLOGY & VERSION NUMBER	IPCC AR5, TRACI 2.1 and CML v4.2

The PCR review was conducted by:	NSF International PCR Review Panel ncss@nsf.org
This declaration was independently verified in accordance with ISO 14025: 2006. ☐ INTERNAL ☒ EXTERNAL	Cooper McCollum, UL Solutions
This life cycle assessment was conducted in accordance with ISO 14044 and the reference PCR by:	Sphera
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	Jack Geibig, Ecoform

LIMITATIONS

Exclusions: EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, environmental impact assessments, etc.

Accuracy of Results: EPDs regularly rely on estimations of impacts; the level of accuracy in estimation of effect differs for any particular product line and reported impact.

Comparability: EPDs from different programs may not be comparable. Full conformance with a PCR allows EPD comparability only when all stages of a life cycle have been considered. However, variations and deviations are possible". Example of variations: Different LCA software and background LCI datasets may lead to differences results for upstream or downstream of the life cycle stages declared.

Product Definition and Information

Description of Company/Organization

For more than 160 years, Johns Manville (JM) has been dedicated to providing products that create stronger buildings, improve energy efficiency, and contribute to the health and comfort of building occupants.

JM manufactures premium-quality building and mechanical insulation, commercial roofing, glass fibers and nonwoven materials for commercial, industrial, and residential applications. JM products are used in a wide variety of industries including building products, aerospace, automotive and transportation, filtration, commercial interiors, waterproofing and wind energy.

JM employs 8,000 people globally and provides products to more than 85 countries. JM operates 44 manufacturing facilities in North America, Europe, and China. Since 1988, JM's global headquarters has been located in downtown Denver, Colorado.

Product Description

Product Identification

Thermoplastic polyolefin (TPO) single-ply roofing membranes are typically utilized in mechanically attached commercial roofing systems and provide excellent long term weatherability, hail resistance and repairability. JM TPO gives you a more cost-effective, yet highly reliable solution for commercial roofing projects. The TPO membranes are reinforced with a polyester fabric and manufactured with an ultraviolet-resistant thermoplastic polyolefin formulation. This combination provides extreme pliability, flexibility and weldability.

The following Johns Manville TPO products are covered by this environmental product declaration:

- JM TPO Roofing Membrane – 45, 60 and 80 mils
- JM TPO Self Adhered – 60 mils
- JM TPO Fleece Backed Membrane for Hot Asphalt Application
- JM TPO Fleece Backed Roofing Membrane

Product Specification

Table 1 below lists the product specification (based on declared unit) representative of the TPO membranes covered by this EPD.

Table 1. TPO membrane technical specifications

JOHNS MANVILLE TPO SINGLE-PLY ROOFING MEMBRANES					
Declared unit	1 m^2 of TPO single-ply roofing membrane with a thickness of 45 mils, 60 mils or 80 mils				
Specification	45 mils	60 mils	80 mils	60 mils (fleece-backed)	80 mils (fleece-backed)
Thickness [mm]	1.14	1.52	2.03	1.52	2.03
Mass [kg]	1.22	1.49	2.04	1.69	2.26
Standard	ASTM D6878 – Standard Specification for Thermoplastic Polyolefin-based Sheet Roofing				

Product Average

This EPD is intended to represent company-specific thermoplastic polyolefin membranes. The production data used to develop this EPD considers the manufacturing activities at the Johns Manville Scottsboro, AL site. Results are allocated according the product density provided by Johns Manville. Use of this EPD is limited to Johns Manville.

Application

TPO membranes are typically utilized in mechanically attached commercial roofing systems and provide excellent long term weatherability, hail resistance, and repairability. TPO membranes are typically used in low slope (roof slope < 2:12), however they can also be used in steep slope applications. The maximum slope roof membrane products can be used at is typically determined by the maximum slope they can achieve and still meet building code required fire classifications.
There are many variables that must be considered when deciding which single ply membrane to select for a particular job. Some examples of variables that should be considered are meeting local building and energy code requirements, roof layout, required design life, cost (initial and over the required design life), and product installation expertise of the roofing contractor.

Declaration of Methodological Framework

This EPD is declared under a “cradle-to-gate with options” system boundary. As such, it includes life cycle stages A1-A3 and C1-C4. It should be noted here that the deconstruction of the membrane is a manual process so C1 is reported as zero. There is also no waste processing to be considered as all membranes are sent to landfill at end-of-life and as such C3 is to be reported as zero. C2 is assumed as 20 miles by truck.

Per the PCR (UL Environment, 2018), the assessment was conducted using a building service life of 75 years.

Technical Requirements

The technical specifications below apply to products considered in this EPD:

- ASTM D6878 – Standard Specification for Thermoplastic Polyolefin-Based Sheet Roofing

Properties of Declared Product as Delivered

TPO membranes are delivered to the customer as packaged.

Material Composition

Table 2 provides the average material content of TPO single-ply roofing membranes.

Table 2. Average TPO membrane material composition

Component	Content [% weight]
Base resin	64.7%
Fire retardant	19.9%
Polyester scrim	8.0%
Stabilizing agents	3.4%
Pigments	3.8%

Polyester fleece	0.3%

Manufacturing

The main material input into the TPO manufacturing process is the base resin in the form of pellets and processed scrap. Additional materials include those which enhance the membrane's performance (e.g., fire retardants and pigments). The mix is heated and either extruded subsequently onto both sides of the reinforcing polyester scrim or extruded at half of the specified thickness with reinforcing polyester scrim pressed in between the top and bottom layers, forming the final TPO membrane sheet. The membrane sheet is then cooled as it runs through a series of rollers. Finally, the product is transferred onto large cardboard rolls and wrapped in plastic film to be shipped to building sites for installation. Figure 1 shows the manufacturing process for TPO (certain aspects may vary by manufacturer).

Figure 1. TPO membrane production process map

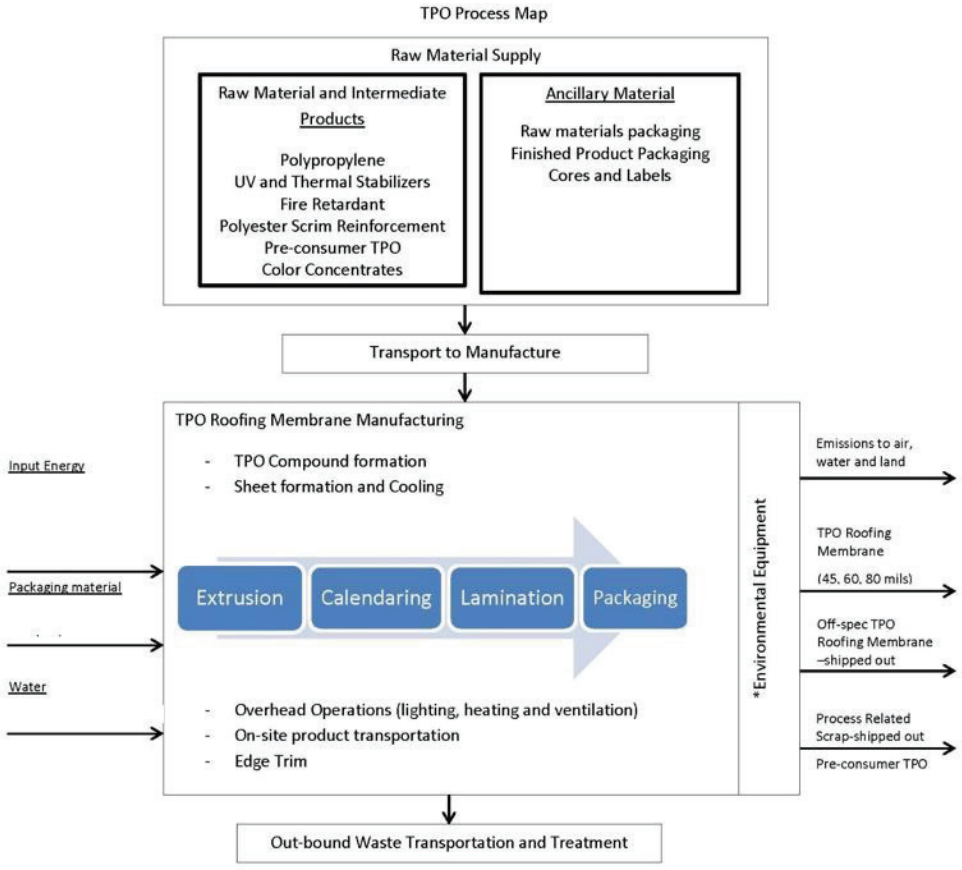
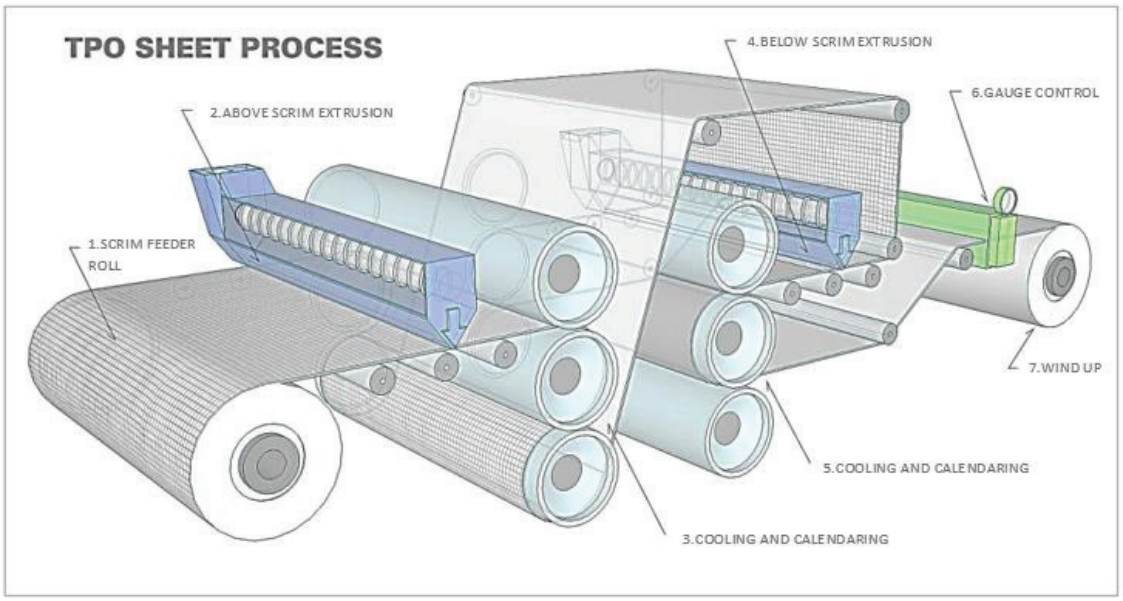


Figure 2 below displays a process schematic for the manufacturing of TPO membrane.

Figure 2. TPO production process schematic



Packaging

Once produced, the TPO membranes are rolled onto cardboard cores then wrapped using plastic film onto wooden pallets.

Transportation

Primary data included transportation distances via truck or rail for the transport of the raw materials to the production facilities. Transport of the deconstructed product at end-of-life to disposal facilities has also been included.

Product Installation

Installation is outside the scope of this EPD and as such, the disposal of the packaging is also outside of the scope of this EPD.

Use

Product use is outside the scope of this EPD.

Reference Service Life and Estimated Building Service Life

Since use phase has been excluded from system boundary, no RSl has been declared for this product.

Reuse, Recycling, and Energy Recovery

Product reuse, recycling and incineration for energy recovery is outside the scope of this EPD.

Disposal

The TPO membranes are assumed to be manually removed from the installation site. In this EPD, the impacts of landfilling scenario is declared as the most common disposal option.

Life Cycle Assessment Background Information

Declared Unit

Per the product category rules, the declared unit for this analysis is :

1 m^2 of single-ply roofing membrane

System Boundary

Table 3 represents the system boundary and scope.

Table 3. 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	B6	B7	C1	C2	C3	C4	D
Raw material supply	Transport	Manufacturing	Transport from gate to site	Assembly/Install	Use	Maintenance	Repair	Replacement	Refurbishment	Building Operational Energy Use During Product Use	Building Operational Water Use During Product Use	Deconstruction	Transport	Waste processing	Disposal	Reuse, Recovery, Recycling Potential
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	X	X	X	X	MND

This study covers the life cycle of the products from cradle to gate (manufacturing) with options (end of life). Within these boundaries, the following stages were included as per Figure 3 below:

- **Raw materials acquisition:** Raw material supply (including virgin and recycled materials), inbound transport
- **Manufacturing:** Production of insulation, product packaging, manufacturing waste, releases to environment
- **End-of-Life:** Dismantling/demolition, transport to final disposal site, final disposition

Figure 3: Life cycle stages included in system boundary

Building operational energy and water use are considered outside of this study's scope: any beneficial impact that the use of insulation may have on a building's energy consumption is not calculated or incorporated into the analysis.

Estimates and Assumptions

All raw materials and energy inputs have been modeled using processes and flows that closely follow actual production data on raw materials and processes. All reported materials and energy flows have been accounted for. No significant assumptions have been made beyong the aforementioned.

Proxy data were applied to some mateirals where no matching life cycle inventories were available, as documented in the background report.

The analysis uses the following assumptions:

- The packaging removal which occurs during the TPO membrane installation (A5) is excluded from this study.
- The TPO membranes are collected and transported by to landfill at end-of-life.

Since primary data were not available to describe end-of-life treatment, a default transportation distance of 20 miles to disposal was applied.

Cut-off Criteria

Per the PCR, the cut-off criteria for flows to be considered within each system boundary are as follows:

- Mass: If a flow is less than 1% of the cumulative mass of the model flows, it may be excluded, provided its environmental relevance is minor, based on a sensitivity analysis.
- Energy: If a flow is less than 1% of the cumulative energy of the system model, it may be excluded, provided its environmental relevance is minor, based on a sensitivity analysis.
- Environmental relevance: If a flow meets the above two criteria but is determined to contribute 2% or more to the selected impact categories of the products underlying the EPD, based on a sensitivity analysis, it is included within the system boundary.

At least 95% of the mass flows shall be included and the life-cycle impact data shall contain at least 95% of all elementary flows that contribute to each of the declared category indicators. A list of hazardous and toxic materials and substances shall be included in the inventory and the cut-off rules do not apply to such substances.

No cut-off criteria had to be applied for this study. All available energy and material flow data were included in the model.

Data Sources

Since the site manufactures membranes with different thicknesses from the same production line, it was not possible to distinguish between the raw materials during data collection period. In order to resolve this issue, data were collected as a total and later allocated based on the overall production quantities of different products and thicknesses. Note that, the Scottsboro, AL site only produces 45 mils, 60 mils (regular & fleece backed), 80 mils (regular & fleece backed) products.

The LCA model was created using the LCA for Experts software system for life cycle engineering, version 10.9, developed by Sphera (Sphera, 2024). Background life cycle inventory data for raw materials and processes were obtained from the Managed LCA Content 2021 databases. Johns Manville provided primary manufacturing data for the calendar year 2019. The background life cycle inventory datatasets are mentioned in Table 4.

Table 4. Background datasets used in inventory analysis

Data	Geographic Reference	Dataset	Data Provider	Ref. Year	Proxy?*
Energy					
Electricity	US	Electricity grid mix – SRSO	Sphera	2021	No
Propane	US	Propane at refinery	Sphera	2020	No
Thermal energy	US	Thermal energy from natural gas	Sphera	2020	No
Material / Process					
Pigment	US	Carbon black (furnace black; general purpose) - thermal energy credit	Sphera	2023	No
TPO base resin	US	Polypropylene / Ethylene Propylene Diene Elastomer Granulate (PP/EPDM, TPE-O)	Sphera	2023	No
Fire retardant	EU-28	Magnesium Hydroxide (from sea water)	Sphera	2023	Geo.
N-dioctadecylhydroxylamine	DE	Dodecanoic acid (Lauric acid)	Sphera	2020	Geo.
PET fleece	DE	PET fleece (1 sqm)	Sphera	2023	Geo.
Polyester scrim	EU-28	Polyester (PET) fabric	Sphera	2023	Geo.
Processing aid	US	Polyethylene Low Density Granulate (LDPE/PE-LD)	Sphera	2023	Tech.
Pigment	US	Titanium dioxide pigment (sulphate process)	Sphera	2023	No
Polypropylene granulate	US	Polypropylene granulate (PP)	Sphera	2023	No
Tris(2,4-ditert-butylphenyl)phosphite	DE	Tris(chloro-ethyl)phosphate	Sphera	2020	Geo.
Packaging					
Testliner	EU-28	Testliner (2018) – for use in cut-off EoL scenario cases	Sphera	2023	Geo.
Corrugated board	EU-28	Corrugated board 2018, average composition, for use in cut-off EoL scenario cases	Sphera	2023	Geo.
Polyester	US	Polyester (PET) fabric	Sphera	2023	No
Polyethylene film	US	Polyethylene film (LDPE/PE-LD)	Sphera	2023	No
Wooden pallets	EU-28	Wooden pallets (EURO, 120x80x14 cm, 22% moisture, 18% H_2O content)	Sphera	2023	Geo.
Processes					
Waste water	US	Municipal waste water treatment (mix)	Sphera	2023	No
Tap water	US	Tap water from groundwater	Sphera	2023	No

Glass/inert waste	EU-28	Glass/inert waste on landfill	Sphera	2020	Geo.
Glass/inert waste	US	Glass/inert on landfill	Sphera	2020	No.
Transportation Mode					
Truck	US	Truck - TL/dry van (EPA SmartWay)	Sphera	2023	No
Rail	GLO	Rail transport cargo - Diesel, average train, gross tonne weight 1,000t / 726t payload capacity	Sphera	2023	No
Transportation Fuel					
Diesel	US	Diesel mix at refinery	Sphera	2020	No

* No = no proxy used

Data Quality

As the majority of the relevant foreground data are measured data or calculated based on primary information sources of the owner of the technology, precision is considered to be high. Seasonal variations were balanced out by using annual production volume. All background data are sourced from Managed LCA Content databases with the documented precision. Each foreground process was checked for mass balance and completeness of the emission inventory. No data were knowingly omitted. Completeness of foreground unit process data is considered to be high. All background data are sourced from Managed LCA Content databases with the documented completeness.

Period under Review

Primary data collected represent production during the 2019 calendar year. This analysis is therefore intended to represent production, primarily in 2019. All secondary data come from the Managed LCA Content databases and are representative of the years 2020-2023.

Allocation

As several products are manufactured at the same plant at one given time, Johns Manville collected their aggregated annual production data. The different TPO membranes . Mass allocation was selected since the environmental burden in the industrial process (energy consumption, emissions, etc.) is primarily governed by the mass throughput of each sub-process.

Allocation of background data (energy and materials) taken from the Managed LCA Content (previously GaBi databases) 2021 databases is documented online at https://sphera.com/product-sustainability-gabi-data-search/.

For disposal at end-of-life, system boundaries were drawn consistent with the cut-off allocation approach and include landfilling of TPO membranes at end-of-life but exclude any avoided burdens from material or energy recovery.

Comparability

Comparisons cannot be made between product-specific or industry average EPDs at the design stage of a project, before a building has been specified. Comparisons may be made between product-specific or industry average EPDs at the time of product purchase when product performance and specifications have been established and serve as a

functional unit for comparison. Environmental impact results shall be converted to a functional unit basis before any comparison is attempted.
Any comparison of EPDs shall be subject to the requirements of ISO 21930 or EN 15804. EPDs are not comparative assertions and are either not comparable or have limited comparability when they have different system boundaries. According to PCR, only EPDs prepared from cradle-to-grave life-cycle results, and based on the same function, quantified by the same functional unit, and taking account of replacement based on the product reference service life (RSL) relative to an assumed building service life, can be used to assist purchasers and users in making informed comparisons between products.— EPDs based on cradle-to-gate and cradle-to-gate with options information modules shall not be used for comparisons. Also, EPDs based on a declared unit shall not be used for comparisons.

Audience

The intended audience of this EPD is business-to-business (BTB) stakeholders, as the scope of the study does not extend to cradle-to-grave analysis, excluding business-to-consumer (BTC) applications.

Life Cycle Assessment Scenarios

Although Module A5 (Construction/Installation stage) is not included in this study, the biogenic carbon content (BCRK) of bio-based packaging materials leaving the product system must still be reported as per the PCR for Single Ply Roofing Membranes.

The total biogenic carbon content (BCRK) in the packaging materials is mentioned for each TPO product in Table 5. In the absence of modeled disposal pathways, it is assumed that all stored biogenic carbon is fully released at the system exit, resulting in BCEK values equal to the total BCRK.

Table 5. Carbon Emissions and Removals (A5)

NAME	45 MILS	60 MILS	80 MILS	60 MILS (FLEECE-BACKED)	80 MILS (FLEECE-BACKED)	UNIT
Biogenic Carbon Removal and Storage Factor (BCRK)	1.72E-01	2.09E-01	2.87E-01	2.38E-01	3.18E-01	kg CO_2 eq
Biogenic Carbon Emission Factor (BCEK)	1.72E-01	2.09E-01	2.87E-01	2.38E-01	3.18E-01	kg CO_2 eq

Table 6. End of life (C1-C4)

NAME		45MILS	60 MILS	80 MILS	60 MILS (FLEECE-BACKED)	80 MILS (FLEECE-BACKED)	UNIT
Assumptions for scenario development (description of deconstruction, collection, recovery, disposal method and transportation)		Membranes are collected manually and shipped by truck to a landfill site (transportation distance of 20 miles) - applicable to all thicknesses					
Collection process (specified by type)	Collected separately	1.22	1.49	2.04	1.69	2.26	kg
	Collected with mixed construction waste	-	-	-	-	-	kg
Recovery (specified by type)	Reuse	-	-	-	-	-	kg
	Recycling	-	-	-	-	-	kg
	Landfill						kg
	Incineration	-	-	-	-	-	kg
	Incineration with energy recovery	-	-	-	-	-	kg
	Energy conversion efficiency rate	-	-	-	-	-	
Disposal (specified by type)	Product or material for final deposition						kg
Removals of biogenic carbon (excluding packaging)		-	-	-	-	-	kg CO_2

Life Cycle Assessment Results

The following results are based on a declared unit of 1 m^2 of TPO membrane. The following results exclude biogenic carbon as there are no relevant biogenic carbon removals or emissions in the life cycle. There is no calcination, carbonation and combustion of waste from non-renewable sources. Also, since cut off approach has been implemented in EOL, there is no energy recovered from landfilling of maunfatured waste. No components for reuse are reported in the results section, as the only reusable material is internal manufacturing scrap, which is looped back within the system boundary.

Impact assessment and other results are shown for a cradle-to-gate with end-of-life options (C1-C4). Modules C1 and C3 are not associated with any impact and are therefore declared as zero. Emerging LCA impact categories and inventory items are still under development and can have high levels of uncertainty that preclude international acceptance pending further development. Use caution when interpreting data in these categories:

— renewable primary energy resources as energy (fuel), (RPRE);

— renewable primary resources as material, (RPRM);

— non-renewable primary resources as energy (fuel) ,(NRPRE);

— non-renewable primary resources as material (NRPRM);

— secondary materials (SM);

— renewable secondary fuels (RSF);

— non-renewable secondary fuels (NRSF);

— recovered energy (RE);

— hazardous waste disposed;

— non-hazardous waste disposed;

— high-level radioactive waste;

— intermediate and low-level radioactive waste;

Life Cycle Impact Assessment Results

Table 7. North American Impact Assessment Results

	A1	A2	A3	C2	C4
Global Warming Potential [kg CO2 eq.]					
TPO 45 mils	3.13E+00	3.62E-02	2.46E-01	3.92E-04	7.37E-02
TPO 60 mils	3.80E+00	4.40E-02	2.99E-01	4.76E-04	8.95E-02
TPO 80 mils	5.21E+00	6.04E-02	4.10E-01	6.52E-04	1.23E-01
TPO 60 mils (fleece backed)	4.33E+00	5.02E-02	3.41E-01	5.42E-04	1.02E-01
TPO 80 mils (fleece backed)	5.78E+00	6.70E-02	4.55E-01	7.24E-04	1.36E-01
Ozone Depletion Potential [kg CFC-11 eq.]					
TPO 45 mils	1.21E-13	9.90E-17	2.20E-14	1.20E-18	3.44E-15
TPO 60 mils	1.47E-13	1.20E-16	2.67E-14	1.46E-18	4.18E-15
TPO 80 mils	2.02E-13	1.65E-16	3.66E-14	2.01E-18	5.73E-15

TPO 60 mils (fleece backed)	1.68E-13	1.37E-16	3.05E-14	1.67E-18	4.77E-15
TPO 80 mils (fleece backed)	2.24E-13	1.83E-16	4.06E-14	2.23E-18	6.36E-15
Acidification Potential [kg SO2 eq.]					
TPO 45 mils	4.60E-03	2.53E-04	2.64E-04	1.22E-06	3.72E-04
TPO 60 mils	5.59E-03	3.08E-04	3.21E-04	1.48E-06	4.52E-04
TPO 80 mils	7.67E-03	4.22E-04	4.40E-04	2.03E-06	6.20E-04
TPO 60 mils (fleece backed)	6.37E-03	3.51E-04	3.66E-04	1.69E-06	5.15E-04
TPO 80 mils (fleece backed)	8.51E-03	4.69E-04	4.89E-04	2.25E-06	6.88E-04
Eutrophication Potential [kg N eq.]					
TPO 45 mils	3.11E-04	2.04E-05	5.86E-05	1.25E-07	1.60E-05
TPO 60 mils	3.78E-04	2.47E-05	7.11E-05	1.52E-07	1.95E-05
TPO 80 mils	5.18E-04	3.39E-05	9.75E-05	2.08E-07	2.67E-05
TPO 60 mils (fleece backed)	4.31E-04	2.82E-05	8.11E-05	1.73E-07	2.22E-05
TPO 80 mils (fleece backed)	5.75E-04	3.76E-05	1.08E-04	2.31E-07	2.96E-05
Smog Formation Potential [kg O3 eq.]					
TPO 45 mils	1.02E-01	8.39E-03	6.04E-03	2.79E-05	6.66E-03
TPO 60 mils	1.24E-01	1.02E-02	7.34E-03	3.38E-05	8.09E-03
TPO 80 mils	1.70E-01	1.40E-02	1.01E-02	4.64E-05	1.11E-02
TPO 60 mils (fleece backed)	1.41E-01	1.16E-02	8.36E-03	3.86E-05	9.22E-03
TPO 80 mils (fleece backed)	1.88E-01	1.55E-02	1.12E-02	5.15E-05	1.23E-02
Abiotic Depletion Potential (ADP fossil) [MJ]					
TPO 45 mils	7.25E+01	4.84E-01	3.02E+00	5.35E-03	1.06E+00
TPO 60 mils	8.81E+01	5.88E-01	3.66E+00	6.50E-03	1.28E+00
TPO 80 mils	1.21E+02	8.05E-01	5.02E+00	8.91E-03	1.76E+00
TPO 60 mils (fleece backed)	1.00E+02	6.70E-01	4.18E+00	7.41E-03	1.46E+00
TPO 80 mils (fleece backed)	1.34E+02	8.94E-01	5.57E+00	9.89E-03	1.95E+00

Life Cycle Inventory Results

Table 8. Resource Use

	A1	A2	A3	C2	C4
Renewable Primary Energy Resources as Energy (RPRe) [MJ]					
TPO 45 mils	3.98E+00	2.13E-02	7.71E-01	2.39E-04	1.35E-01
TPO 60 mils	4.84E+00	2.58E-02	9.37E-01	2.90E-04	1.64E-01
TPO 80 mils	6.63E+00	3.54E-02	1.28E+00	3.98E-04	2.25E-01
TPO 60 mils (fleece backed)	5.51E+00	2.95E-02	1.07E+00	3.31E-04	1.87E-01
TPO 80 mils (fleece backed)	7.36E+00	3.93E-02	1.43E+00	4.42E-04	2.49E-01
Renewable Primary Resources as Material (RPRm) [MJ]					
TPO 45 mils	0.00E+00	0.00E+00	1.83E+00	0.00E+00	0.00E+00
TPO 60 mils	0.00E+00	0.00E+00	2.22E+00	0.00E+00	0.00E+00
TPO 80 mils	0.00E+00	0.00E+00	3.05E+00	0.00E+00	0.00E+00

TPO 60 mils (fleece backed)	0.00E+00	0.00E+00	2.53E+00	0.00E+00	0.00E+00
TPO 80 mils (fleece backed)	0.00E+00	0.00E+00	3.38E+00	0.00E+00	0.00E+00
Non-Renewable Primary Resources as Energy (fuel) (NRPRe) [MJ]					
TPO 45 mils	4.03E+01	4.87E-01	3.19E+00	5.40E-03	1.09E+00
TPO 60 mils	4.90E+01	5.92E-01	3.87E+00	6.56E-03	1.32E+00
TPO 80 mils	6.72E+01	8.12E-01	5.31E+00	8.99E-03	1.81E+00
TPO 60 mils (fleece backed)	5.59E+01	6.75E-01	4.41E+00	7.48E-03	1.51E+00
TPO 80 mils (fleece backed)	7.46E+01	9.01E-01	5.89E+00	9.98E-03	2.01E+00
Non-Renewable Primary Resources as Material (NRPRm) [MJ]					
TPO 45 mils	3.45E+01	0.00E+00	7.65E-01	0.00E+00	0.00E+00
TPO 60 mils	4.20E+01	0.00E+00	9.29E-01	0.00E+00	0.00E+00
TPO 80 mils	5.75E+01	0.00E+00	1.27E+00	0.00E+00	0.00E+00
TPO 60 mils (fleece backed)	4.78E+01	0.00E+00	1.06E+00	0.00E+00	0.00E+00
TPO 80 mils (fleece backed)	6.38E+01	0.00E+00	1.41E+00	0.00E+00	0.00E+00
Secondary Materials (SM) [kg]					
TPO 45 mils	0.00E+00	0.00E+00	6.64E-02	0.00E+00	0.00E+00
TPO 60 mils	0.00E+00	0.00E+00	8.07E-02	0.00E+00	0.00E+00
TPO 80 mils	0.00E+00	0.00E+00	1.11E-01	0.00E+00	0.00E+00
TPO 60 mils (fleece backed)	0.00E+00	0.00E+00	9.20E-02	0.00E+00	0.00E+00
TPO 80 mils (fleece backed)	0.00E+00	0.00E+00	1.23E-01	0.00E+00	0.00E+00
Renewable Secondary Fuels (RSF) [MJ]					
TPO 45 mils	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TPO 60 mils	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TPO 80 mils	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TPO 60 mils (fleece backed)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TPO 80 mils (fleece backed)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Non-Renewable Secondary Fuels (NRSF) [MJ]					
TPO 45 mils	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TPO 60 mils	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TPO 80 mils	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TPO 60 mils (fleece backed)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TPO 80 mils (fleece backed)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of net fresh water (FW) [m^3]					
TPO 45 mils	1.28E-02	7.14E-05	1.70E-03	7.94E-07	1.41E-04
TPO 60 mils	1.55E-02	8.67E-05	2.06E-03	9.64E-07	1.71E-04
TPO 80 mils	2.13E-02	1.19E-04	2.83E-03	1.32E-06	2.34E-04
TPO 60 mils (fleece backed)	1.77E-02	9.88E-05	2.35E-03	1.10E-06	1.95E-04
TPO 80 mils (fleece backed)	2.36E-02	1.32E-04	3.14E-03	1.47E-06	2.60E-04

Table 9. Output Flows and Waste Categories

	A1	A2	A3	C2	C4
Hazardous Waste Disposed (HWD) [kg]					
TPO 45 mils	1.40E-08	6.59E-11	9.47E-09	7.28E-13	2.69E-10
TPO 60 mils	1.70E-08	8.01E-11	1.15E-08	8.84E-13	3.27E-10
TPO 80 mils	2.32E-08	1.10E-10	1.58E-08	1.21E-12	4.48E-10
TPO 60 mils (fleece backed)	1.93E-08	9.13E-11	1.31E-08	1.01E-12	3.72E-10
TPO 80 mils (fleece backed)	2.58E-08	1.22E-10	1.75E-08	1.35E-12	4.97E-10
Non-Hazardous Waste Disposed (NHWD) [kg]					
TPO 45 mils	5.63E-01	4.83E-05	3.97E-03	5.38E-07	3.33E+00
TPO 60 mils	6.84E-01	5.86E-05	4.82E-03	6.54E-07	4.04E+00
TPO 80 mils	9.37E-01	8.04E-05	6.61E-03	8.96E-07	5.54E+00
TPO 60 mils (fleece backed)	7.79E-01	6.68E-05	5.50E-03	7.45E-07	4.61E+00
TPO 80 mils (fleece backed)	1.04E+00	8.92E-05	7.34E-03	9.95E-07	6.15E+00
High-level radioactive waste, conditioned, to final repository (HLRW) [kg]					
TPO 45 mils	8.93E-07	1.58E-09	3.90E-07	1.93E-11	1.29E-08
TPO 60 mils	1.08E-06	1.92E-09	4.74E-07	2.34E-11	1.57E-08
TPO 80 mils	1.49E-06	2.63E-09	6.49E-07	3.21E-11	2.16E-08
TPO 60 mils (fleece backed)	1.24E-06	2.19E-09	5.40E-07	2.67E-11	1.79E-08
TPO 80 mils (fleece backed)	1.65E-06	2.92E-09	7.21E-07	3.57E-11	2.39E-08
Intermediate- and low-level radioactive waste, conditioned, to final repository (ILLRW) [kg]					
TPO 45 mils	8.60E-04	1.35E-06	3.36E-04	1.64E-08	1.18E-05
TPO 60 mils	1.04E-03	1.64E-06	4.08E-04	2.00E-08	1.43E-05
TPO 80 mils	1.43E-03	2.24E-06	5.59E-04	2.74E-08	1.96E-05
TPO 60 mils (fleece backed)	1.19E-03	1.87E-06	4.65E-04	2.28E-08	1.63E-05
TPO 80 mils (fleece backed)	1.59E-03	2.49E-06	6.21E-04	3.04E-08	2.17E-05

LCA Interpretation

The cradle-to-gate potential environmental impacts of TPO membranes in all life cycle impact categories are driven by the raw materials (A1). Inbound transport to manufacturing (A2) and membrane manufacturing (A3) contribute to potential environmental impacts on a smaller order of magnitude.

Additional Environmental Information

Environment and Health During Manufacturing

Johns Manville roofing products are designed, manufactured and tested in our own facilities, which are certified and registered to the stringent ISO 9001 (ANSI/ASQC 90) and ISO 14001 quality and environmental standards. These certifications, along with regular, independent third-party auditing for compliance, is your assurance that JM products deliver consistent high quality.

Environment and Health During Installation

More details on installation is available at https://www.jm.com/en/commercial-roofing/tpo-design-and-installation-considerations/.

Building Use Stage Benefits

The lighter-colored JM TPO reflects solar energy to lower the amount of heat absorbed into the building, greatly reducing air-conditioning energy loads and costs.

White JM TPO membrane meets the stringent requirements for both LEED® (Leadership in Energy and Environmental Design) and California Title 24 when tested by the CRRC® (Cool Roof Rating Council).

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