

ENVIRONMENTAL PRODUCT DECLARATION

According to ISO 14025 and ISO 21930:2017

TPO SINGLE PLY ROOFING MEMBRANE

SINGLE PLY ROOFING INDUSTRY (SPRI)

INDUSTRY AVERAGE EPD



About SPRI

SPRI is the recognized technical and statistical authority on the Single Ply Roofing Industry. SPRI provides the best forum for its members to collectively focus their industry expertise and efforts on critical industry issues. By acting as a trade organization, as opposed to each member working individually, the group can effectively improve product quality, installation techniques, workforce training and other issues common to the industry. This approach enables every SPRI member to operate more effectively in the commercial roofing marketplace.

SPRI represents sheet membrane and related component suppliers in the commercial roofing industry.

Since 1981, SPRI has been an excellent resource for building owners, architects, engineers, specifiers, contractors and maintenance personnel, providing objective information about commercial roofing components and systems.



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Declaration Number: ASTM-EPD 446

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DECLARATION INFORMATION

Declaration	
Program Operator: ASTM International Company: Single Ply Roofing Industry 465 Waverley Oaks Road, Suite 421 Waltham, MA 02452 Tel: (781) 647-7026 Email: info@spri.org	 www.astm.org
Product Information	Validity / Applicability
Product Name: TPO Single Ply Roofing Membrane	Period of Validity: This declaration is valid for a period of 5 years from the date of publication.
Product Definition: Thermoplastic Polyolefin (TPO) Single Ply Roofing Membrane	
Declaration Type: Business-to-business (B2B)	Geographic Scope: North America
PCR Reference: - Core PCR: ISO 21930:2017 (ISO, 2017) - Sub-category PCR: Product Category Rules for Single Ply Roofing Membranes (ASTM International, 2019)	PCR Review was conducted by: - Thomas P. Gloria, Ph.D., Industrial Ecology Consultants - Bill Stough, Sustainable Research Group - Jack Geibig, EcoForm
Product Application and/or Characteristics	
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.	
Content of the Declaration	
- Product definition and physical building-related data - Details of raw materials and material origin - Description of how the product is manufactured - Life Cycle Assessment results	
Verification	
Independent verification of the declaration and data, according to ISO 21930:2017 and ISO 14025:2006	☐ internal ☒ external
This declaration and the rules on which this EPD is based have been examined by an independent verifier in accordance with ISO 14025.	
<i>Limitations</i> The environmental impact results of TPO products in this document are based on a declared unit and therefore do not provide sufficient information to establish comparisons. The results shall not be used for comparisons without knowledge of how the physical properties of the TPO product impact the precise function at the construction level. The environmental impact results shall be converted to a functional unit basis before any comparison is attempted. Environmental declarations from different programs (ISO 14025) may not be comparable.	



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EPD SUMMARY

This document is a Type III environmental product declaration by Single Ply Roofing Industry (SPRI) that is certified by ASTM International (ASTM) as conforming to the requirements of ISO 21930 and ISO 14025. ASTM has assessed that the Life Cycle Assessment (LCA) information fulfills the requirements of ISO 14040 and 14044 in accordance with the instructions listed in the referenced product category rules. The intent of this document is to further the development of environmentally compatible and sustainable construction methods by providing comprehensive environmental information related to potential impacts in accordance with international standards.

No comparisons or benchmarking is included in this EPD. Environmental declarations from different programs based upon differing PCRs may not be comparable. In general, EPDs may not be used for comparability purposes when not considered in a construction works context. Given this PCR ensures products meet the same functional requirements, comparability is permissible provided the information given for such comparison is transparent and the limitations of comparability explained. 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. When comparing EPDs created using this PCR, variations and deviations are possible. Example of variations: Different LCA software and background LCI datasets may lead to different results for upstream or downstream of the life cycle stages declared.

SCOPE AND BOUNDARIES OF THE LIFE CYCLE ASSESSMENT

The Life Cycle Assessment (LCA) was performed according to ISO 14040 (ISO, 2020a) and ISO 14044 (ISO, 2020b) following the requirements of the ASTM EPD Program Instructions and the referenced PCR.

System Boundary: Cradle-to-gate

Allocation Method: No multi-output allocation was required in the foreground system of the study..

Declared Unit: 1 m² of single ply roofing membrane for a stated product thickness. Environmental performance results therefore represent the industry average production of 1 m² of TPO roofing membrane product.



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GENERAL INFORMATION

DESCRIPTION OF COMPANY/ORGANIZATION

The following SPRI members provided data for the product under study:



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



Johns Manville
P. O. Box 5108717
17th Street
Denver, CO 80217-5108
www.jm.com



Holcim Building Envelope
26 Century Blvd., Suite 205
Nashville, TN 37214
www.holcimbe.com/en



IKO Industries Inc.
6 Denny Road, Suite 200
Wilmington, DE 19809
www.iko.com/na

PRODUCT DESCRIPTION

The product system evaluated in this report is an installed single ply TPO roofing membrane at the finished nominal thicknesses produced by SPRI members. See Table 1 for membrane specification and standard.

Table 1 Membrane specification and standard

Roof System	Roofing System Component	Thickness and Reference Weights	Standard
Thermoplastic Polyolefin (TPO)	Membrane	45 mils: 1.15 kg/m ² 60 mils: 1.48 kg/m ² 80 mils: 2.02 kg/m ²	ASTM D6878

PRODUCT AVERAGE

The production data used in this EPD was collected for the year 2019 for six production sites. For the seventh production site, primary data was collected for four months beginning December 2021 to March 2022 and extrapolated for a year. An exception was from one of the participating companies that provided data for the year 2021/2022 collected over 4 months and extrapolated to the full year. The company stated that 2021/2022 data was selected as they only recently started TPO production in 2020. Moreover, this plant was not fully operational until approximately December 2021. The plant was in the initial trial stages of qualification until approximately December 2021. Hence, the data prior to this time would not be representative of their current manufacturing process. The production data considers TPO roofing membranes produced by participating members of SPRI in seven (7) sites in the United States.

The participating facilities are:



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Carlisle	Holcim	Johns Manville	IKO
Tooele, UT	Muscle Shoals, AL	Scottsboro, AL	Hagerstown, MD
Carlisle, PA	Wellford, SC		
Senatobia, MS			

Results are weighted according to production totals at participating facilities.

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.

MATERIAL COMPOSITION

Table 2 shows the input material for TPO roofing membranes and their weighted average material percentages across the three membrane thicknesses.

Table 2 Weighted average composition of TPO roofing membrane

Material	% Weighted Average Composition
Base resin (PP)	57.41%
TPO scrap (internal)	3.48%
Fire retardant	21.85%
PET Scrim	6.48%
Polyolefins	2.11%
LLDPE	0.12%
Stabilizing agents	5.50%
Adhesive	0.53%
Pigment	1.84%
Needle fleece	0.59%
Other additives	0.09%

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



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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).

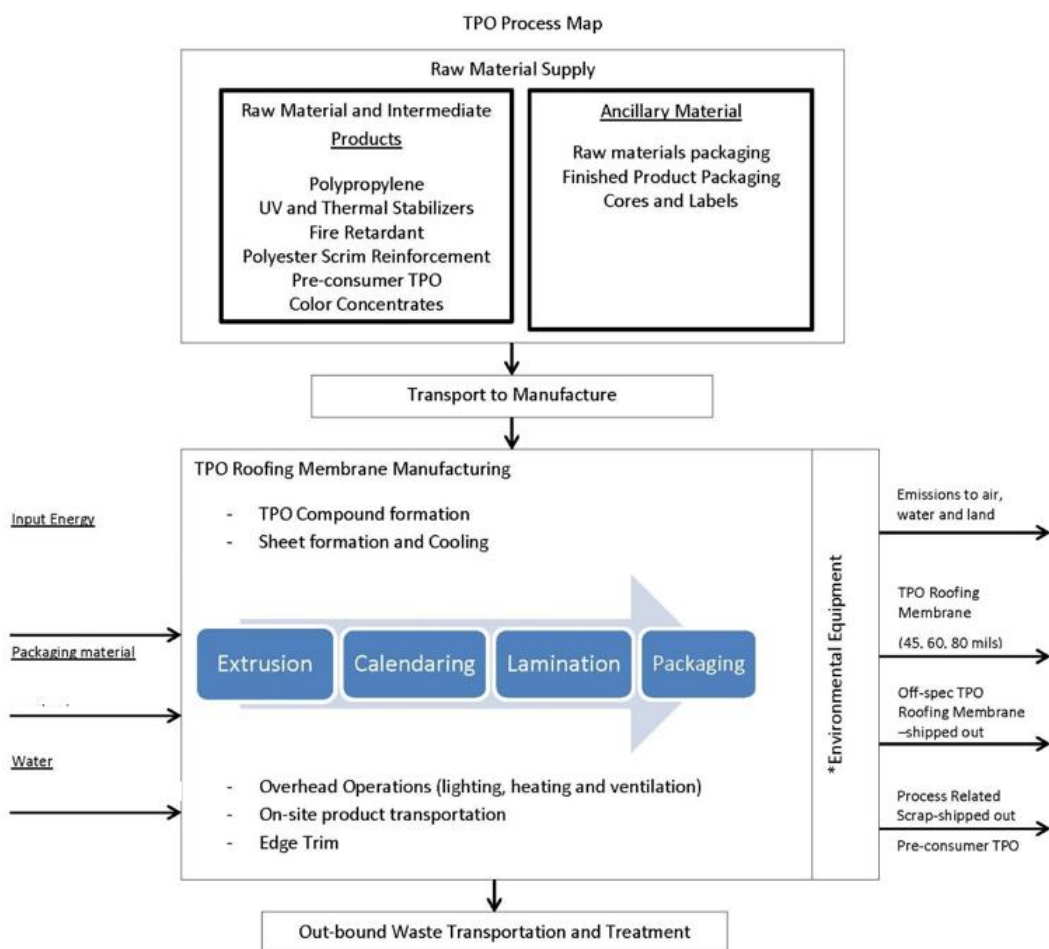


Figure 1. TPO production process map (courtesy of Johns Manville)

According to ISO 14025 and ISO 21930:2017

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

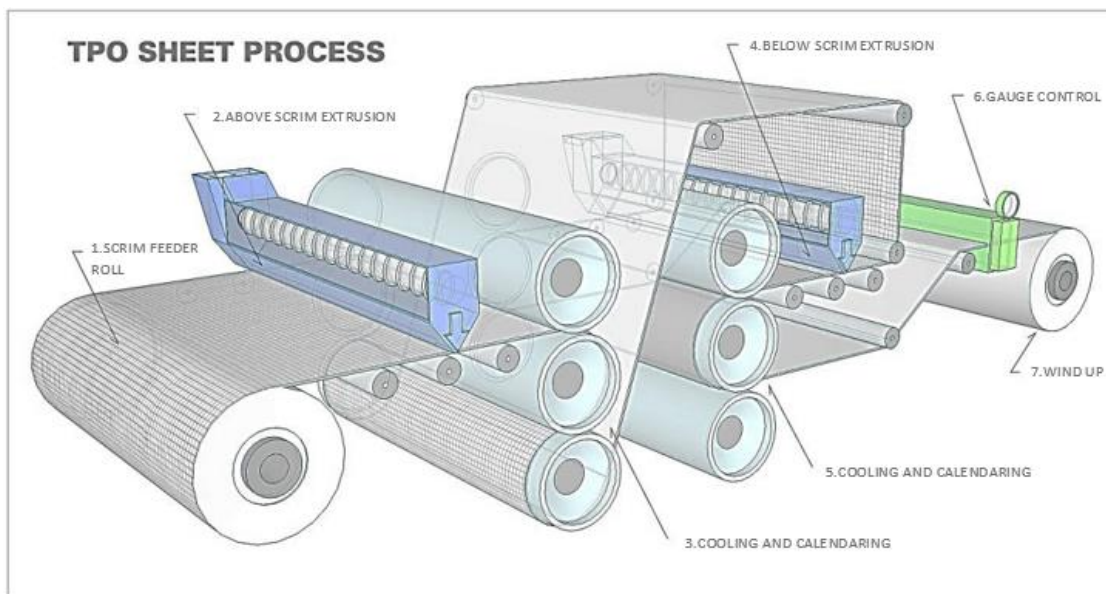


Figure 2. TPO production process schematic (courtesy of Johns Manville)

TRANSPORTATION

Primary data on inbound transportation of raw materials and packaging materials were collected. The raw materials included base resin (PP), scrim, fillers, pigments, curatives, activators, processing aids, etc. Transportation to the customer or construction site is outside the scope of this EPD.

PRODUCT INSTALLATION

Installation is outside the scope of this EPD.

USE

Product use is outside the scope of this EPD.

REUSE, RECYCLING, AND ENERGY RECOVERY

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

DISPOSAL

Product disposal is outside the scope of this EPD.



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METHODOLOGICAL FRAMEWORK

DECLARED UNIT

The declared unit is 1 m² of single ply roofing membrane for a stated product thickness. Environmental performance results therefore represent the industry average production of 1 m² of TPO membranes. The reference service life is not specified. Because the use stage is not included in the system boundary, no reference service life needs to be defined for the analysis.

SYSTEM BOUNDARY

System boundaries are summarized in Figure 2 for the analysis scope of "cradle-to-gate". Excluded modules are indicated by "MND" or "module not declared". As is typical of works of life cycle assessment, the construction and maintenance of capital equipment, such as production equipment in the manufacturing stage, are not included in the system, nor are human labor and employee commute. The use stage is also outside the scope of this study.

PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY
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
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND

Figure 3 Life cycle stages included in system boundary

CUT-OFF RULES

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



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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

The LCA model was created using the LCA for Experts software system for life cycle engineering, version 10, developed by Sphera (Sphera, 2021). Background life cycle inventory data for raw materials and processes were obtained from the Managed LCA Content 2021 databases. Participating companies (Carlisle, Firestone, Johns Manville and IKO) provided primary manufacturing data for the year 2019 (with the exception of one company, which provided data from 2021/22).

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 yearly averages that were then weighted according to each manufacturer's 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.

GEOGRAPHICAL COVERAGE

This study represents seven SPRI member companies with facilities across the United States. As such, the geographical coverage for this study is based on US system boundaries for all processes and products.

Regionally specific datasets, where available, were used to represent each manufacturing location's energy consumption. Proxy datasets were used as needed for raw material inputs to address lack of data for a specific material or for a specific geographical region. These proxy datasets were chosen for their technological representativeness of the actual materials.

PERIOD UNDER REVIEW

Primary data collected represent production during the 2019 calendar year (except for one participating member that provided data from 2021/2022, because data before that period would not be representative of their current manufacturing process). This analysis is therefore intended to represent production, primarily in 2019, save this exception from one participating member. All secondary data come from the Managed LCA Content databases and are representative of the years 2017-2020.

ALLOCATION

As several products are often manufactured at the same plant, participating companies used mass allocation to report data. 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/>.



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ESTIMATES AND ASSUMPTIONS

In cases where no matching life cycle inventories were available to represent a flow, proxy data were applied based on conservative assumptions regarding environmental impacts.

LIFE CYCLE ASSESSMENT RESULTS

The environmental impacts associated with the TPO roofing membrane is presented below in Table 3 for the production stage (A1-A3). The life cycle impact assessment results, listed in Table 3 are calculated according to TRACI 2.1 indicators, with the exception of Global Warming Potential (calculated according to IPCC AR5 indicators), in accordance with ISO 21930: 2017.

Indicator	A1	A2	A3	Total
Global Warming Potential [kg CO₂ eq.]				
TPO 45 mils	3.01E+00	4.89E-02	2.60E-01	3.32E+00
TPO 60 mils	3.88E+00	6.39E-02	3.39E-01	4.29E+00
TPO 80 mils	5.49E+00	8.99E-02	4.78E-01	6.05E+00
Ozone Depletion Potential [kg CFC-11 eq.]				
TPO 45 mils	9.08E-15	8.72E-18	1.10E-12	1.11E-12
TPO 60 mils	1.16E-14	1.14E-17	1.41E-12	1.42E-12
TPO 80 mils	1.65E-14	1.60E-17	1.99E-12	2.00E-12
Acidification Potential [kg SO₂ eq.]				
TPO 45 mils	5.80E-03	3.89E-04	4.06E-04	6.60E-03
TPO 60 mils	7.50E-03	5.09E-04	5.29E-04	8.54E-03
TPO 80 mils	1.06E-02	7.15E-04	7.45E-04	1.21E-02
Eutrophication Potential [kg N eq.]				
TPO 45 mils	1.02E-03	3.19E-05	5.91E-05	1.12E-03
TPO 60 mils	1.33E-03	4.17E-05	7.65E-05	1.45E-03
TPO 80 mils	1.89E-03	5.86E-05	1.08E-04	2.06E-03
Smog Formation Potential [kg O₃ eq.]				
TPO 45 mils	1.18E-01	1.32E-02	7.32E-03	1.38E-01
TPO 60 mils	1.53E-01	1.72E-02	9.54E-03	1.79E-01
TPO 80 mils	2.15E-01	2.42E-02	1.34E-02	2.53E-01



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The resource use associated with the TPO roofing membrane is presented below in Table 4 for the production stage (A1-A3).

Indicator	A1	A2	A3	Total
Renewable Primary Energy Resources as Energy (RPRE) [MJ]				
TPO 45 mils	3.14E+00	2.83E-02	0.00E+00	3.17E+00
TPO 60 mils	4.04E+00	3.70E-02	0.00E+00	4.08E+00
TPO 80 mils	5.73E+00	5.20E-02	0.00E+00	5.78E+00
Renewable Primary Resources as Material (RPRM) [MJ]				
TPO 45 mils	0.00E+00	0.00E+00	3.11E+00	3.11E+00
TPO 60 mils	0.00E+00	0.00E+00	3.90E+00	3.90E+00
TPO 80 mils	0.00E+00	0.00E+00	5.54E+00	5.54E+00
Non-Renewable Primary Resources as Energy (fuel) (NRPRE) [MJ]				
TPO 45 mils	8.34E+01	6.97E-01	4.14E+00	8.82E+01
TPO 60 mils	1.08E+02	9.11E-01	5.40E+00	1.14E+02
TPO 80 mils	1.52E+02	1.28E+00	7.61E+00	1.61E+02
Non-Renewable Primary Resources as Material (NRPRM) [MJ]				
TPO 45 mils	0.00E+00	0.00E+00	2.68E-01	2.68E-01
TPO 60 mils	0.00E+00	0.00E+00	3.50E-01	3.50E-01
TPO 80 mils	0.00E+00	0.00E+00	4.96E-01	4.96E-01
Secondary Materials (SM) [kg]				
TPO 45 mils	0.00E+00	0.00E+00	6.16E-02	6.16E-02
TPO 60 mils	0.00E+00	0.00E+00	7.87E-02	7.87E-02
TPO 80 mils	0.00E+00	0.00E+00	1.11E-01	1.11E-01
Renewable Secondary Fuels (RSF) [MJ]				
TPO 45 mils	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
TPO 80 mils	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
TPO 60 mils	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
Use of net fresh water (FW) [m³]				
TPO 45 mils	6.12E-02	1.22E-04	2.30E-03	6.36E-02
TPO 60 mils	7.94E-02	1.60E-04	2.99E-03	8.26E-02
TPO 80 mils	1.13E-01	2.24E-04	4.22E-03	1.18E-01

The waste generation associated with the TPO roofing membrane is presented below in Table 5 for the production stage (A1-A3).



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Indicator	A1	A2	A3	Total
Hazardous Waste Disposed (HWD) [kg]				
TPO 45 mils	3.05E-08	5.85E-11	1.82E-08	4.87E-08
TPO 60 mils	4.16E-08	7.64E-11	2.33E-08	6.50E-08
TPO 80 mils	5.82E-08	1.07E-10	3.29E-08	9.11E-08
Non-Hazardous Waste Disposed (NHWD) [kg]				
TPO 45 mils	1.40E-01	6.33E-05	5.06E-02	1.91E-01
TPO 60 mils	1.80E-01	8.28E-05	6.83E-02	2.48E-01
TPO 80 mils	2.54E-01	1.16E-04	9.42E-02	3.48E-01
Radioactive Waste Disposed (RWD) [kg]				
TPO 45 mils	8.24E-04	1.74E-06	3.24E-04	1.15E-03
TPO 60 mils	1.06E-03	2.27E-06	4.22E-04	1.48E-03
TPO 80 mils	1.50E-03	3.19E-06	5.95E-04	2.10E-03

The statistical metrics for the LCIA results presented in Table 3 have been shown in Table 6 for 1 m² of TPO membranes for each of the three thicknesses for the production stage (A1-A3) across all facilities.

Table 6: Statistical metrics of LCIA results (A1-A3) per 1 m² of TPO membranes of different thicknesses across all facilities

LCIA Impact Category	Unit	Min	Max	Max/Min Ratio	Mean	Median
45 mils						
Global warming potential (GWP)	[kg CO ₂ eq.]	2.72E+00	3.36E+00	1.24E+00	3.01E+00	3.06E+00
Acidification potential (AP)	[kg SO ₂ eq.]	5.84E-03	8.02E-03	1.37E+00	6.66E-03	6.23E-03
Eutrophication potential (EP)	[kg N eq.]	4.10E-04	1.89E-03	4.62E+00	1.11E-03	1.17E-03
Ozone Depletion potential (ODP)	[kg CFC 11 eq.]	6.41E-13	1.62E-12	2.52E+00	1.10E-12	1.08E-12
Smog Formation Potential (SFP)	[kg O ₃ eq.]	1.15E-01	1.67E-01	1.45E+00	1.38E-01	1.28E-01
60 mils						
Global warming potential (GWP)	[kg CO ₂ eq.]	3.42E+00	4.38E+00	1.28E+00	3.89E+00	3.85E+00
Acidification potential (AP)	[kg SO ₂ eq.]	7.56E-03	1.04E-02	1.38E+00	8.61E-03	8.04E-03
Eutrophication potential (EP)	[kg N eq.]	4.98E-04	2.46E-03	4.95E+00	1.44E-03	1.61E-03
Ozone Depletion potential (ODP)	[kg CFC 11 eq.]	8.83E-13	2.14E-12	2.42E+00	1.41E-12	1.36E-12
Smog Formation Potential (SFP)	[kg O ₃ eq.]	1.53E-01	2.20E-01	1.44E+00	1.78E-01	1.68E-01
80 mils						
Global warming potential (GWP)	[kg CO ₂ eq.]	4.72E+00	5.97E+00	1.26E+00	5.29E+00	5.28E+00
Acidification potential (AP)	[kg SO ₂ eq.]	1.04E-02	1.42E-02	1.37E+00	1.17E-02	1.08E-02
Eutrophication potential (EP)	[kg N eq.]	6.83E-04	3.36E-03	4.93E+00	1.97E-03	2.17E-03
Ozone Depletion potential (ODP)	[kg CFC 11 eq.]	1.19E-12	2.84E-12	2.39E+00	1.92E-12	1.88E-12
Smog Formation Potential (SFP)	[kg O ₃ eq.]	2.10E-01	2.94E-01	1.40E+00	2.42E-01	2.27E-01



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LCA INTERPRETATION

The cradle-to-gate potential environmental impacts of TPO membranes in all life cycle impact categories (except ozone depletion potential) 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. For ozone depletion potential, inbound transportation is the primary contributor for TPO membranes of all thickness.

Disclaimer (quoted from sub-category PCR):

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);
- hazardous waste disposed;
- non-hazardous waste disposed;
- Radioactive Waste Disposed (RWD);

REFERENCES

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CONTACT INFORMATION

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ENVIRONMENTAL PRODUCT DECLARATION

According to ISO 14025 and ISO 21930:2017

TPO Single Ply Roofing Membrane

LCA PRACTITIONER



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