ENVIRONMENTAL PRODUCT DECLARATION

TPO MEMBRANE

SINGLE PLY ROOFING MEMBRANE
INSTALLATION: MECHANICALLY FASTENED

Singly ply, TPO membrane mechanically fastened and representative of 45, 60, and 80 mil thicknesses

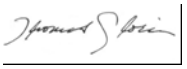
SPRI is the recognized technical and statistical authority on the Single Ply Roofing Industry. SPRI provides the best forum for its members to collectively focus their industry expertise and efforts on critical industry issues. By acting as a trade organization, as opposed to each member working individually, 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.

CERTIFIED
ENVIRONMENTAL PRODUCT DECLARATION
UL.COM/EPD

This declaration is an environmental product declaration (EPD) in accordance with ISO 14025. EPDs rely on Life Cycle Assessment (LCA) to provide information on a number of environmental impacts of products over their life cycle. 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, and the level of accuracy in estimation of effect differs for any particular product line and reported impact. Comparability: EPDs are not comparative assertions and are either not comparable or have limited comparability when they cover different life cycle stages, are based on different product category rules or are missing relevant environmental impacts. EPDs from different programs may not be comparable.

PROGRAM OPERATOR	UL Environment
DECLARATION HOLDER	Single Ply Roofing Industry (SPRI)
DECLARATION NUMBER	4786842353.102.1
DECLARED PRODUCT	TPO Single Ply Roofing Membrane (Mechanically Fastened)
REFERENCE PCR	PCR for Single Ply Roofing Membranes. ASTM International
DATE OF ISSUE	September 23, 2016
PERIOD OF VALIDITY	5 Years
CONTENTS OF THE DECLARATION	Product definition and information about building physics Information about basic material and the material's origin Description of the product's manufacture Indication of product processing Information about the in-use conditions Life cycle assessment results Testing results and verifications

The PCR review was conducted by:	PCR Review Panel
	Peer review report available upon request
	cert@astm.org
This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories ☐ INTERNAL ☒ EXTERNAL	
	Wade Stout, UL Environment
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	
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Participating Members

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

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Product Definition

Description of Product

The product system evaluated in this report is an installed single ply TPO roofing membrane at the finished nominal thicknesses listed in Table 1.

Table 1: Membrane specification and standard

Roof System	Roof System Component	Declared Thicknesses and Weights	Standard
Thermoplastic polyolefin (TPO)	Membrane	45 mils: 1.20 kg/m^2 60 mils: 1.55 kg/m^2 80 mils: 2.10 kg/m^2	ASTM D6878

Application and Uses

TPO membranes are typically used in low slope roofs (slope < 2:12), however they can also be used in steep slope applications. For example, there are some PVC membranes that are designed to provide the visual appearance of a standing seam metal roof. 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 (e.g. are there numerous penetrations?), required design life, cost (initial and over the required design life), and product instillation expertise of the roofing contractor.

Installation

The installation process was modeled following common practice in which TPO membrane is mechanically fastened. The most common low slope roof consists of a metal deck, then a layer of insulation; cover board (optional) and then the roof membrane. For mechanically attached systems, the insulation and cover boards (if present) are screwed directly to the metal deck below. Typically a mechanically attached single ply membrane is installed by rolling out the membrane screws are then drilled in at the edge of the membrane to the metal deck below and then covered with the edge of the next sheet as the rolls are successively put down. A watertight seal is created by either heat-welding or taping the membranes together. This seals any gaps and creates a single, flat, waterproof surface.

Product Life Cycle Description

Material Content

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

Table 2: Average composition of TPO roofing membrane

Material	45 mils [%]	60 mils [%]	80 mils [%]
Base resin (PP/EPDM)	74	74	76
Fire retardants	13	14	12
Polyester scrim	6	6	6
Pigments	4	4	4
Weathering agents	3	2	<1
Anti-oxidizing agents	<1	<1	<1
Stabilizers	<1	<1	<1
Compounding agents	<1	<1	<1

Manufacturing Process

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 aid the manufacturing process (e.g., accelerators) and those which enhance the membrane's performance (e.g., fire retardants and pigments). The mix is heated and either extruded simultaneously 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 product is cooled as it runs through a series of rollers, after which it is transferred onto large cardboard rolls and wrapped in plastic film to be shipped to building sites for installation.

Figure **Error! Reference source not found.**1 shows the manufacturing process for TPO (certain aspects may vary by manufacturer), while Figure 2 displays a process schematic for the manufacturing of TPO membrane.

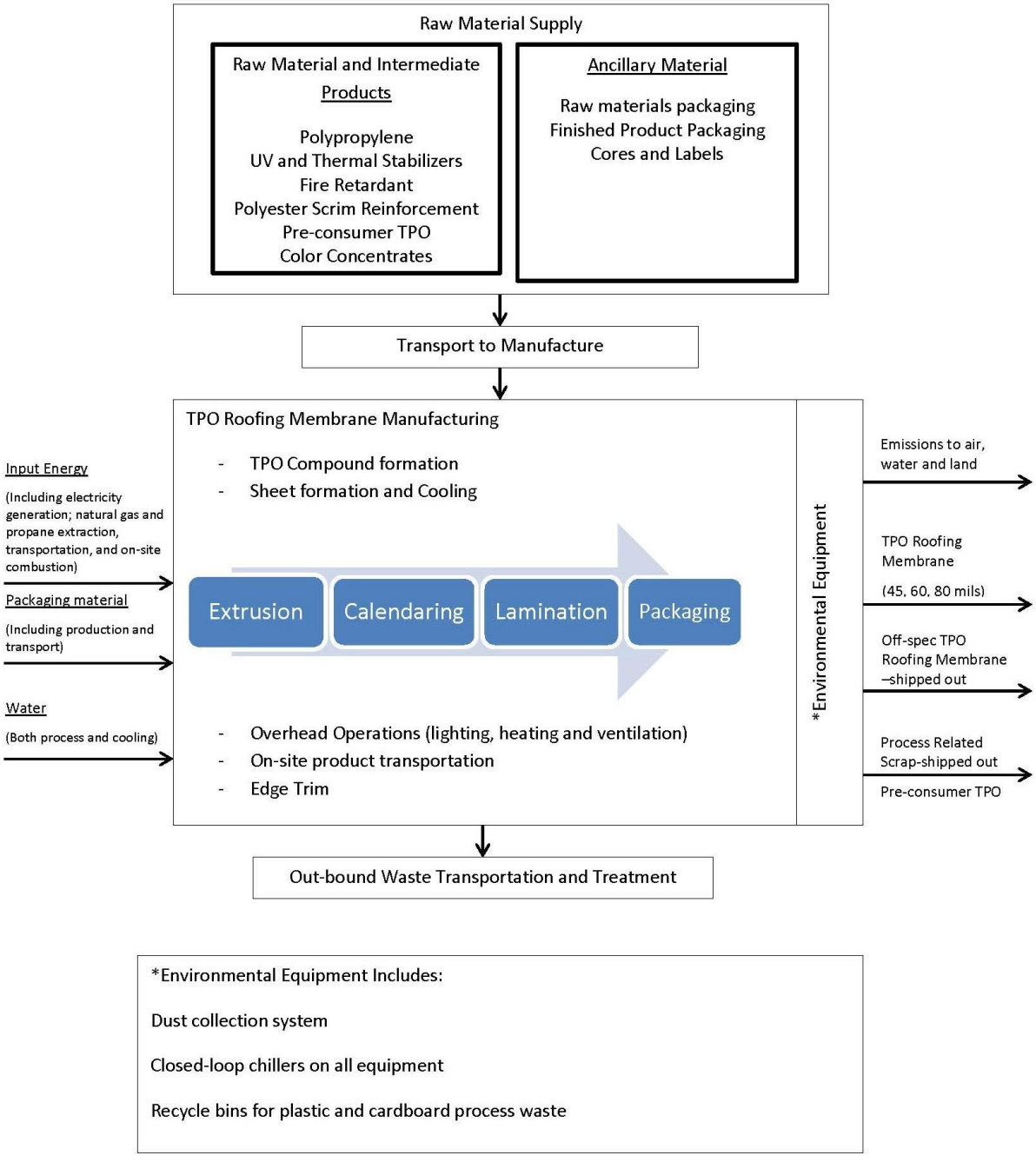

Figure 1: TPO production process map (courtesy of Johns Manville)

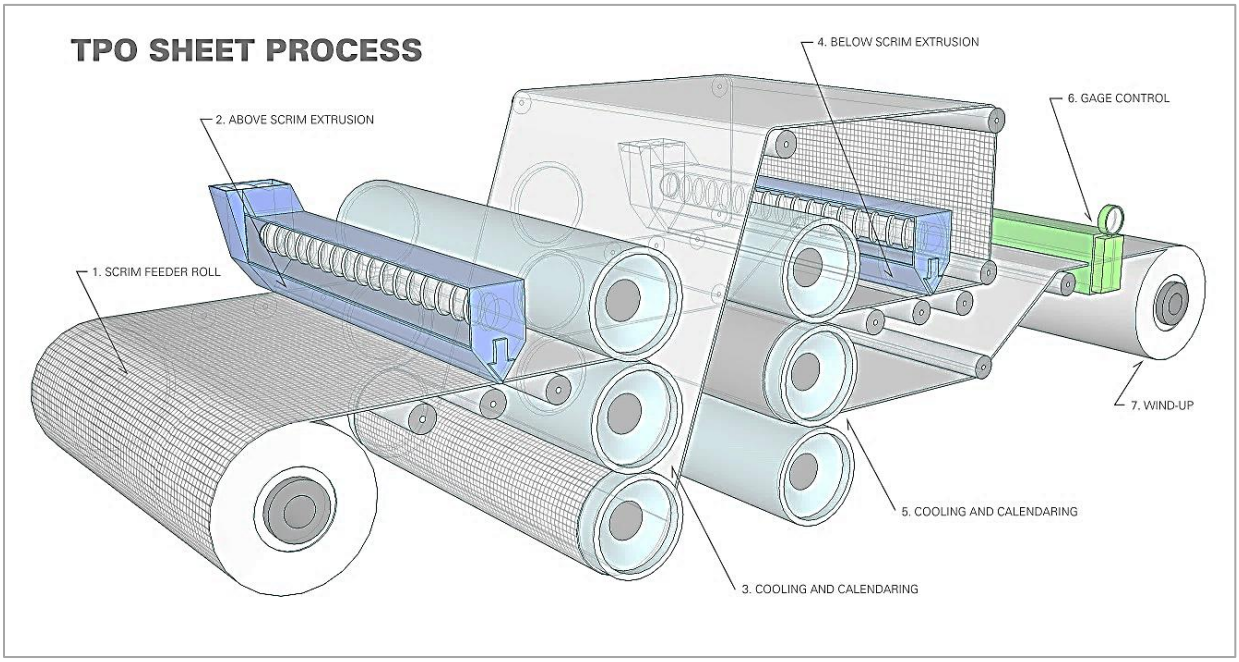

Figure 2: TPO production process schematic (courtesy of Johns Manville)

Installation

Table 3 shows the production-weighted industry average material inputs, material outputs, and emissions associated with the installation of 1 m^2 of TPO membrane. This scenario is based on information provided by four SPRI members and is intended to represent a typical installation. It is assumed to be representative for all thicknesses. Packaging materials are disposed of after the membrane is installed at the building site.

Table 3: Installation of TPO membrane, unit process (per declared unit)

I/O	Material	Value	Unit
Inputs	TPO roofing membrane (packaged), incl. 2.5% overlap	1.025	m^2
	Steel fasteners	0.0242	kg
	Electricity for power tools	0.00360	MJ
Outputs	1 m^2 of installed TPO roofing membrane	1	m^2
	Packaging waste (from membrane)	*	kg

* varies with membrane thickness

End-of-Life

At the end of the roofing membrane's useful life, it was assumed that the membrane material, as well as any fasteners or adhesive substances, are manually removed from the building and then landfilled. This disposal method was most commonly practiced at the time of this study, according to the reporting manufacturers. Transport to landfill was

approximated with 20 miles via large dump truck.

Life Cycle Assessment – Product Systems and Modeling

Declared Unit

The declared unit evaluated is 1 m^2 of single ply roofing membrane for a stated product thickness. As the use stage is excluded from this study, no reference service life is defined.

Life Cycle Stages Assessed

The life cycle assessment (LCA) conducted includes the production, transport to installation site, installation, and end-of-life (EoL) stages.

System Boundaries

System boundaries are summarized in Figure 2 for the analysis scope of “cradle-to-building with EoL stage” (i.e., production with installation and EoL stages). 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			
Raw material supply	**Transport**	**Manufacturing**	**Transport**	**Construction-installation process**	**Use**	**Maintenance**	**Repair**	**Replacement**	**Refurbishment**	**Operational energy use**	**Operational water use**	**De-construction demolition**	**Transport**	**Waste processing**	**Disposal**
A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**
X	X	X	X	X	MND	MND	MND	MND	MND	MND	MND	X	X	X	X

Figure 3: Life cycle stages included in system boundary

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.

Transportation

Unless specified by manufacturers, estimated transportation distances and modes of transport are included for the transport of the raw materials, operating materials and auxiliary materials to production facilities.

Period under Consideration

All primary data were collected for the year 2014. All secondary data come from the GaBi Professional databases and are representative of the years 2010-2013.

Manufacturing Locations

This study represents four SPRI member companies with facilities across the United States, including Alabama, Indiana, Mississippi, South Carolina, Texas, and Utah. As such, the geographical coverage for this study is based on US system boundaries for all processes and products. Whenever US background data were not readily available, European data or global data were used as proxies.

Background Data

The LCA model was created using the GaBi ts software system for life cycle engineering, developed by thinkstep AG. The GaBi Professional LCI database provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

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 Quality Requirements

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 GaBi 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 GaBi databases with the documented completeness.

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.

Life Cycle Assessment – Results and Analysis

Use of Material Resources

The material resource consumption associated with the TPO roofing membranes are presented below in Table 4 for the production (A1-A3), transport to installation site (A4), installation (A5), and EoL (C1-C4) stages.

Table 4: Use of material resources for TPO membrane, per declared unit

Indicator	Production A1-A3	Transport to Site A4	Installation A5	EoL C1-C4	Total
Non-renewable materials [kg]					
TPO 45 mils	4.59	0.00156	0.0811	0.276	**4.95**
TPO 60 mils	5.97	0.00206	0.0859	0.355	**6.42**
TPO 80 mils	8.36	0.00270	0.0915	0.480	**8.94**
Renewable materials [kg]					
TPO 45 mils	1,540	1.16	23.6	23.8	**1,590**
TPO 60 mils	1,870	1.52	22.6	30.6	**1,920**
TPO 80 mils	2,350	2.00	21.6	41.4	**2,420**
Fresh water [L]					
TPO 45 mils	83.0	0.0683	-0.0317	-0.761	**82.3**
TPO 60 mils	87.6	0.0899	-0.0696	-0.979	**86.6**
TPO 80 mils	59.0	0.118	-0.113	-1.32	**57.7**

* Water consumption values are negative due to waste sent to landfill during construction and at EoL. A landfill introduces blue water to the watershed because it collects rainwater during its lifetime that is eventually released as ground water, therefore more water is coming out of the process than going in. Rainwater is not blue water and is therefore not included in the water consumption metric.

Primary Energy by Life Cycle Stage

The primary energy demand associated with the TPO roofing membranes are presented below in Table 5 for the production (A1-A3), transport to installation site (A4), installation (A5), and EoL (C1-C4) stages.

Table 5: Primary energy consumption results for TPO membrane, per declared unit

Indicator	Production A1-A3	Transport to Site A4	Installation A5	EoL C1-C4	Total
Non-renewable fossil [MJ, LHV]					
TPO 45 mils	92.5	0.341	0.205	0.847	**93.9**
TPO 60 mils	120	0.449	0.195	1.09	**121**
TPO 80 mils	168	0.589	0.187	1.47	**170**
Non-renewable nuclear [MJ, LHV]					
TPO 45 mils	4.01	0.00182	0.0270	0.0236	**4.06**
TPO 60 mils	5.22	0.00239	0.0225	0.0303	**5.27**
TPO 80 mils	7.50	0.00314	0.0182	0.0410	**7.57**
Renewable (solar, wind, hydroelectric, geothermal) [MJ, LHV]					
TPO 45 mils	3.51	0.00537	-0.0930	0.0458	**3.47**
TPO 60 mils	4.30	0.00707	-0.178	0.0588	**4.19**
TPO 80 mils	5.04	0.00929	-0.282	0.0795	**4.85**
Renewable (biomass) [MJ, LHV]					
TPO 45 mils	5.93×10^{-11}	4.43×10^{-15}	2.01×10^{-12}	9.93×10^{-13}	6.23×10^{-11}
TPO 60 mils	7.45×10^{-11}	5.83×10^{-15}	1.95×10^{-12}	1.28×10^{-12}	7.78×10^{-11}
TPO 80 mils	9.80×10^{-11}	7.66×10^{-15}	1.87×10^{-12}	1.72×10^{-12}	1.02×10^{-10}

Life Cycle Impact Assessment

The environmental impacts associated with the TPO roofing membrane is presented below in Table 6 for the production (A1-A3), transport to installation site (A4), installation (A5), and EoL (C1-C4) stages.

Table 6: Life cycle impact category results for TPO membrane, per declared unit

Indicator	Production A1-A3	Transport to Site A4	Installation A5	EoL C1-C4	Total
GWP [kg CO_2-eq]					
TPO 45 mils	3.78	0.0243	0.0426	0.0555	**3.91**
TPO 60 mils	4.95	0.0320	0.0513	0.0714	**5.10**
TPO 80 mils	6.96	0.0420	0.0591	0.0964	**7.15**
AP [kg SO_2-eq]					
TPO 45 mils	0.00954	1.18×10^{-4}	2.80×10^{-4}	8.22×10^{-4}	**0.0108**
TPO 60 mils	0.0125	1.55×10^{-4}	3.58×10^{-4}	0.00106	**0.0140**
TPO 80 mils	0.0176	2.04×10^{-4}	4.32×10^{-4}	0.00144	**0.0197**

Indicator	Production A1-A3	Transport to Site A4	Installation A5	EoL C1-C4	Total
EP [kg N-eq]					
TPO 45 mils	6.99×10^{-4}	1.07×10^{-5}	5.97×10^{-5}	3.05×10^{-4}	**0.00107**
TPO 60 mils	8.83×10^{-4}	1.41×10^{-5}	7.70×10^{-5}	3.95×10^{-4}	**0.00137**
TPO 80 mils	0.00109	1.85×10^{-5}	9.46×10^{-5}	5.35×10^{-4}	**0.00174**
ODP [kg CFC 11-eq]					
TPO 45 mils	4.06×10^{-10}	2.08×10^{-13}	1.32×10^{-13}	1.29×10^{-12}	**4.08×10^{-10}**
TPO 60 mils	5.32×10^{-10}	2.74×10^{-13}	-3.08×10^{-13}	1.66×10^{-12}	**5.34×10^{-10}**
TPO 80 mils	7.77×10^{-10}	3.59×10^{-13}	-7.01×10^{-13}	2.24×10^{-12}	**7.79×10^{-10}**
SFP [kg O_3-eq]					
TPO 45 mils	0.157	0.00372	0.00160	0.00729	**0.169**
TPO 60 mils	0.207	0.00490	0.00190	0.00939	**0.223**
TPO 80 mils	0.291	0.00644	0.00221	0.0127	**0.312**

Waste Generation

The waste generation associated with the TPO roofing membrane is presented below in Table 7 for the production (A1-A3), transport to installation site (A4), installation (A5), and EoL (C1-C4) stages.

Table 7: Waste generation results for TPO membrane, per declared unit

Indicator	Production A1-A3	Transport to Site A4	Installation A5	EoL C1-C4	Total
Waste generated [kg]					
TPO 45 mils	0.199	1.13×10^{-5}	0.125	1.16	**1.48**
TPO 60 mils	0.246	1.49×10^{-5}	0.164	1.49	**1.90**
TPO 80 mils	0.373	1.95×10^{-5}	0.210	2.01	**2.60**

References

- ASTM. (2013). Product Category Rule for Preparing an Environmental Product Declaration for Single Ply Roofing Membranes. West Conshohocken, PA: ASTM International.
- thinkstep. (2014). GaBi LCA Database Documentation. Retrieved from thinkstep AG: http://database-documentation.gabi-software.com

LCA Development

The EPD and background LCA were prepared by thinkstep, Inc.

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