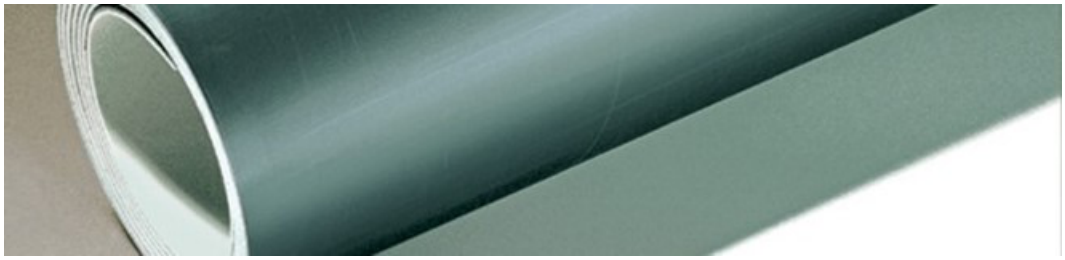
An Environmental Product Declaration

According to ISO 14025:2006 and ISO 21930:2017

An industry average cradle-to-building with EOL stage EPD for white, single-ply polyester reinforced PVC roofing membrane, with a finished nominal thickness of 40, 48, 60 and 80 mils, produced by Chemical Fabrics and Film Association (CFFA), Vinyl Roofing Division member companies for the USA and Canadian Markets.



ASTM International Certified Environmental Product Declaration

This is an industry average (also known as an "industry-wide" or "generic" EPD) business-to-business Type III environmental product declaration for four thicknesses of white, single-ply polyester reinforced (SPPR) PVC roofing membranes (40, 48, 60 and 80 mils). The products covered conform to ASTM D4434 [1] and ASTM D6754 [2]. This EPD was commissioned by Chemical Fabrics and Film Association (CFFA), Vinyl Roofing Division on behalf of PVC roofing manufacturing industry and its members in the US and Canada. This declaration has been prepared in accordance with ISO 21930 [3], ISO 14040 [4], ISO 14044 [5], the governing NSF International product category rules (PCR) for preparing an environmental product declaration for Single Ply Roofing Membranes [6], ASTM International's EPD program operator rules [7], and ISO 14025 [8].

The intent of this document is to further the development of environmentally compatible and more sustainable construction products by providing comprehensive environmental information related to potential environmental impacts of SPPR PVC roofing membranes (40, 48, 60 and 80 mils) available in the USA and Canada in accordance with international standards.

Environmental Product Declaration Summary

General Summary	
Owner of the EPD	**Chemical Fabrics and Film Association (CFFA)** Vinyl Roofing Division- Head office 1300 Sumner Ave. Cleveland, Ohio 44115-2851 Link (URL): www.vinylroofs.org Six CFFA members provided LCI data and meta data for reference year 2018. Combined these six companies represent over 85% of North American production of single-ply polyester reinforced PVC roofing membranes. CFFA and its members provided additional scenario parameter values in the completion of this EPD. *The owner of the declaration is liable for the underlying information and evidence.*

General Summary	
CFFA Member Names, Locations and Brands)	**Canadian General-Tower Limited** 52 Middleton Road, Cambridge, Ontario, Canada N1R 5T6 Member Link (URL): www.cgtower.com
	Carlisle Construction Materials P.O. Box 7000 Carlisle, PA 17013 Member Link (URL): www.carlisleconstructionmaterials.com
	Duro-Last Roofing 525 Morley Drive, Saginaw, MI 48601 Member Link (URL): www.duro-last.com
	FiberTite Roofing Systems 1000 Venture Blvd., Wooster, OH 44691 Member Link (URL): www.seamancorp.com

General Summary

	Thermoplastic Single Ply and Multi-Ply Roofing & Waterproofing Systems **Flex Membrane International Corp.** 2670 Leiscz's Bridge Road Suite 400 Leesport, PA 19533 Member Link (URL): www.flexroofingsystems.com
	Sarnafil BUILDING TRUST Sika **Sika Corporation - Roofing** 100 Dan Road, Canton, MA 02021 Member Link (URL): www.sarnafilus.com
Product Group and Name	Single Ply Roofing Membranes White, SPPR PVC roofing membrane
Product Description	Single-ply roofing membranes are thermoplastic or thermoset membranes of compounded synthetic materials manufactured in a factory for use in roofing [6].
Product Category Rules (PCR)	NSF International, Product Category Rule for Environmental Product Declarations, PCR for Single Ply Roofing Membranes, October 2019 [6]. ISO 21930:2017 serves as the core PCR [3].

Certification Period	21.02.2020 - 20.02.2025
Declared Unit	1 m^2 installed white, SPPR PVC roofing membrane, with a finished nominal thickness of: • 1.016 mm (40 mils) • 1.219 mm (48 mils) • 1.524 mm (60 mils) • 2.032 mm (80 mils)
ASTM Declaration Number	EPD 126

EPD and Project Report Information			
Program Operator		ASTM International	
Declaration Holder		Chemical Fabrics and Film Association (CFFA), Vinyl Roofing Division	
Product group	**Date of Issue**	**Period of Validity**	**Declaration Number**
Single Ply Roofing Membranes	21.02.2020	5 years	EPD 126

Declaration Type

A "Cradle-to-building with end-of-life (EOL) stage" EPD for four thicknesses of white, SPPR PVC roofing membrane (40, 48, 60 and 80 mils). Activity stages covered include the production, construction and EOL stages (modules A1 to A5 and C1 to C4). Module D optional supplementary information beyond the system boundary is reported as well. The declaration is intended for use in Business-to-Business (B-to-B) communication.

Applicable Countries

United States and Canada

Product Applicability

The declared SPPR PVC roofing membrane thicknesses (40, 48, 60 and 80 mils) are designed for low-slope and steep slope roofing applications. The membrane has an internal polyester reinforcement to provide the tear resistance required for mechanically-attached roof systems.

Content of the Declaration

This declaration follows *Section 9*; *Content of an EPD*, NSF International, Product Category Rule for Environmental Product Declarations: PCR for Single Ply Roofing Membranes, October 2019 [6].

EPD and Project Report Information	
This EPD was independently verified by ASTM in accordance with ISO 14025 and the reference PCR: **Internal** **External** X	Timothy Brooke ASTM International 100 Barr Harbor Drive West Conshohocken, PA 19428 tbrooke@astm.org 
The Project Report *Note that this Project Report is not part of the public communication (ISO 21930, 10.1).*	A Cradle-to-building with EOL stage Life Cycle Assessment for four thicknesses of white, SPPR PVC Roofing Membrane (40, 48, 60 and 80 mils), February 2020.
Prepared by Athena Sustainable Materials Institute	Lindita Bushi, Ph.D. and Mr. Jamie Meil Athena Sustainable Materials Institute 280 Albert Street, Suite 404 Ottawa, Ontario, Canada K1P 5G8 info@athenasmi.org www.athenasmi.org
This EPD project report was independently verified by in accordance with ISO 14025, ISO 14040/44, and the reference PCR:	Thomas P. Gloria, Ph. D. Industrial Ecology Consultants 35 Bracebridge Rd. Newton, MA 02459 - 1728 t.gloria@industrial - ecology.com
EPD Explanatory material	For any explanatory material, regarding this EPD, please contact the program operator. ASTM International Environmental Product Declarations 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, http://www.astm.org

PCR Information	
Program Operator	ASTM International
Reference PCR	NSF International, Product Category Rule for Environmental Product Declarations: PCR for Single Ply Roofing Membranes [6]. ISO 21930:2017 serves as the core PCR [3].
Date of Issue	October 2019
PCR review was conducted by:	Thomas P. Gloria, PhD (Chair), Industrial Ecology Consultants, t.gloria@industrial-ecology.com Mr. Jack Geibig, EcoForm Mr. Bill Stough, Sustainable Research Group

1 PRODUCT IDENTIFICATION

1.1 PRODUCT DEFINITION

Per NSF PCR [6], single ply roofing membranes are defined as thermoplastic or thermoset membranes of compounded synthetic materials manufactured in a factory for use in roofing.

A white, SPPR PVC roofing membrane consists of two plies or layers of PVC material with a polyester reinforcement scrim between the layers (Figure 1). The top ply has special additives to make the membrane UV stable, plasticizers to make it flexible, and pigments for color. The bottom ply is typically darker in color containing fewer pigments by weight, but otherwise contains a similar mix of plasticizers, stabilizers, fillers and fire-retardant additives.

The focus of this industry average EPD is on four thicknesses of white, SPPR PVC roofing membrane, produced by member companies with finished nominal thicknesses of:

- 1.016 mm (40 mils),
- 1.219 mm (48 mils),
- 1.524 mm (60 mils), and
- 2.032 mm (80 mils).

The four declared CFFA SPPR PVC roofing membrane thicknesses are designed for low-slope and steep slope roofing applications. Depending on the application, the membranes may be installed as follows:

- mechanically fastened;
- bonded; or
- loosely laid under ballast (e. g. gravel, pavers, vegetation).

“Mechanically fastened” is the most common installation method and is the basis for the installation scenario (A5 module) in this LCA and EPD. “Bonded” and “loosely laid under ballast” roof systems are mentioned for distinction between the individual roofing systems only. These two options are not considered within the EPD.

Table 1 summarizes key technical data for 40, 48, 60 and 80 mils, white, SPPR PVC roofing membrane thicknesses. All four declared thicknesses meet or exceed ASTM D4434 or ASTM D6754 specifications [1], [2].

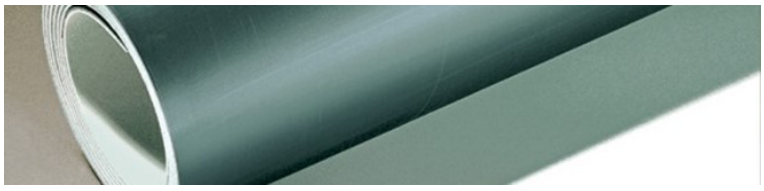


Figure 1 White, SPPR PVC roofing membrane [Photo Courtesy: CFFA 2016]

Table 1: Weighted average technical data of declared thicknesses

Technical data	Units	Value/Test Results			
		40 mils	48 mils	60 mils	80 mils
Weighted average finished density	kg/m^2	1.141	1.470	1.797	2.460
Minimum/Maximum density values	kg/m^2	1.103/1.221	1.422/1.582	1.744/1.933	2.240/2.627
Density variation	%	Less than 10%			
Color	n/a	white			
Weighted average thickness	mm	1.016	1.219	1.524	2.032

1.2 PRODUCT STANDARD

Applicable product standards for four declared products include:

- ASTM D4434/ D4434M - 15 Standard Specification for Poly(Vinyl Chloride) Sheet Roofing.
- ASTM D6754/ D6754M - 15 Standard Specification for Ketone Ethylene Ester Based Sheet Roofing.

2 DECLARED UNIT

Per NSF PCR, Section 7.1.3 [6], the declared unit for this LCA study is defined as 1 m^2 of installed white, SPPR PVC roofing membrane, with a finished nominal thickness of 1.016 mm (40 mils), 1.219 mm (48 mils), 1.524 mm (60 mils), and 2.032 mm (80 mils) (see Table 1).

The color “white” in the context of the declared unit is expressed as roofing membrane having a reflectance, emittance and a combined solar reflectance index (SRI) meeting or exceeding the cool roofing requirements of USGBC's LEED program, Green Globes, ENERGY STAR and California Title 24.

3 MATERIAL CONTENT

Table 2 below presents the weighted average composition for 1 m^2 of the four membranes by input material as derived from the CFFA facilities LCI data for the reference year 2018. PVC resin and plasticizers account for over 73% of the total mass of inputs. The reinforcing scrim accounts for between 6% and 13% of the total mass of inputs.

Table 2: Weighted average material content for 1 m² of white SPPR PVC roofing membrane by thickness

Inputs[1)]	Units	40 mils	48 mils	60 mils	80 mils
PVC Resin[2)]	kg	0.581	0.795	1.034	1.441
Plasticizer	kg	0.331	0.426	0.528	0.733
Pigment	kg	0.050	0.062	0.076	0.093
Fire retardant	kg	0.035	0.044	0.059	0.061
Stabilizer	kg	0.024	0.031	0.039	0.056
Fillers	kg	0.031	0.044	0.056	0.102
Processing aids, oils and lubricants	kg	0.014	0.018	0.023	0.044
Biocide	kg	0.0068	0.0092	0.0110	0.015
Adhesives	kg	0.015	0.016	0.016	0.016
Polyester fabric (scrim reinforcement)	kg	0.162	0.166	0.162	0.162
Total weight input	kg	1.250	1.610	2.003	2.720
Finished density	kg	1.141	1.470	1.797	2.460

Notes:
1) Input data for both face and back ply.
2) It includes the minimal amount of vinyl chloride co-polymer, VCC.
3) Data are rounded to an appropriate number of significant digits (2 to 4).

PVC resin PVC is essentially derived from two ingredients: fossil fuel and salt. Petroleum or natural gas is processed to make ethylene, and salt is subjected to electrolysis to separate out the natural element chlorine. Ethylene and chlorine are combined to produce ethylene dichloride, which is further processed into vinyl chloride monomer (VCM) gas. In the next step, known as polymerization, the VCM molecule forms chains, converting the gas into a fine, white powder “vinyl resin”, which becomes the basis for the next process – compounding. During compounding, vinyl resin is blended with additives such as stabilizers for durability, pigments for color, fire retardant, etc.

Plasticizer Plasticizer is the second main component of the membrane. They contribute to the flexibility of the membrane. Plasticizer consists of phthalate esters and Ketone Ethylene Ester (KEE).

Pigment Titanium dioxide.

Fire retardant Antimony trioxide and alumina trihydrate.

Stabilizer Organic Based Stabilizer (OBS) and other types of stabilizers. OBS stabilizers contain no heavy metals—lead, barium, zinc, tin, or cadmium.

Fillers Calcium Carbonate and synthetic amorphous silica (95%)

Processing aids, oils, lubricants and solvents Epoxidized Soybean Oil (ESO), waxes, epoxy resins, thermoplastic, organic acids and fatty acid esters.

Biocide Complex organic chemical compounds, antimicrobial additives for plastics.

Adhesives Acrylic resins and aromatic diisocyanate.

Scrim reinforcement By weight scrim reinforcement is the third largest material component of the membrane. It's a polyester fibre (PET) with specific density between 2.1 to 7.2 oz/yd^2.

Note: Not all chemicals listed above are contained in each company specific membrane.

4 PRODUCT STAGE

For this EPD, the boundary is "cradle-to-building with EOL stage", which includes the Production stage (A1 to A3 modules), Construction stage (A4-A5 modules), and end-of-life (EOL) stage (C1 to C4 modules). Module D optional supplementary information beyond the system boundary is also included. The Use stage - is excluded from the system boundary (see Figure 2).

Per ISO 21930, 7.1.7.2.1 [2], the system boundary with nature (natural environment) includes those technical processes that provide the material and energy inputs into the system and the subsequent manufacturing and transport processes up to the building including EOL stage, as well as the processing of any waste arising from those processes.

The *Production stage* includes the following three information modules A1 to A3: — A1, extraction and upstream production; — A2, transport to factory; — A3, manufacturing. Figure 3 presents the *Production stage* system boundary for the declared PVC roofing membranes manufacturing.
The *Construction stage* includes the following two information modules A4 to A5: — A4, transport to site (Table 3); — A5, installation (Tables 4 and 5).

For the mechanical fastened installation system, the PVC roofing membranes are rolled out on a suitable substrate (clean, even, solid, on insulation or cover board as required), aligned and fastened with approved fastening systems to the supporting structure according to the manufacturer's specification.

Usually, the fastening is carried out along the membrane overlap (seam area). After installation of the fasteners, seam overlaps are welded for waterproofing. Fasteners may also be placed in the field of the membrane. With mechanical fastening of the roofing membranes, the complete roof build‑up (including thermal insulation, vapor control layer, etc.) is secured to the underlying structure.

The *End-of-Life Stage* includes the following processes (Table 6): — C1, Deconstruction/ Demolition; — C2, Transport to waste processing and/or disposal; — C3, Waste processing of flows resulting in secondary material (post-consumer), materials for reuse (not applicable), or secondary fuels (not applicable); and — C4 Disposal of waste.

The *optional supplementary module D* provides optional supplementary information about the potential net benefits from post-consumer roof recycling beyond the system boundary of the studied PVC roofing membrane system.

The LCA results associated with module D are reported separately. The net output flow for all PVC roofing membranes for secondary material leaving a product system is calculated by adding all output flows of the secondary material and subtracting any input flows of this secondary material from each information module (A1 to A5, C1 to C4) thus arriving at the net output flow of secondary material from the PVC roofing membrane system (Table 7).

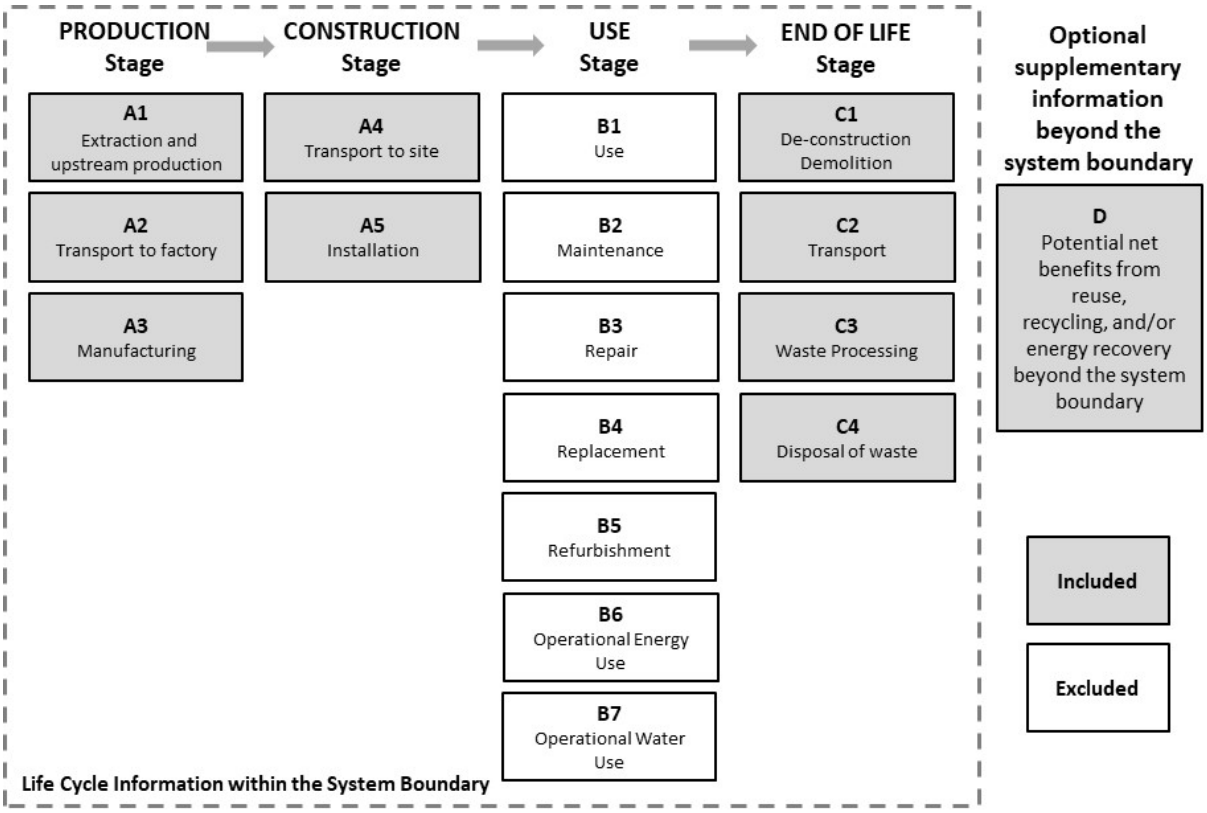


Figure 2 Common four life cycle stages and their information modules for construction products and the optional supplementary module [3]

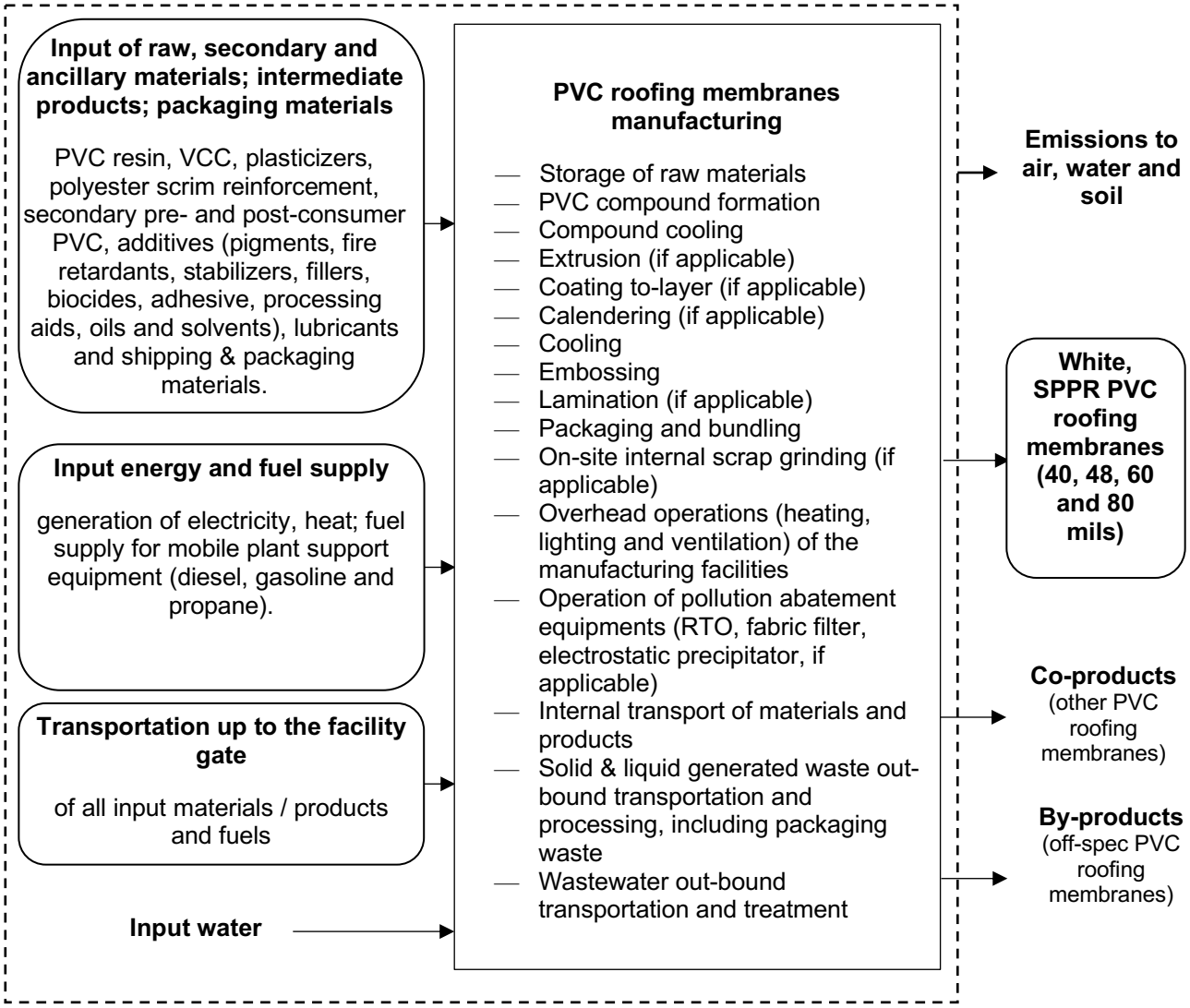


Figure 3 Production stage (module A1 to A3) system boundary of PVC roofing membranes manufacturing

Table 3: A4 Module, Product transport to building site for white SPPR PVC roofing membrane (40, 48, 60 and 80 mils)

Inputs	Units	One-way distance	Comments
Combination truck, diesel, long haul >200 mi	km	947	Manufacturing site to local distributor
Rail, diesel	km	47	
Combination truck, diesel, short haul <200 mi	km	25	Local distributor to building site

Table 4: A5 Module, Installation systems for white SPPR PVC roofing membrane (40, 48, 60 and 80 mils)

Declared membrane	Installation	Seam welding
40 mils	Mechanically fastened	Hot-air welding
48 mils		
60 mils		
80 mils		

Table 5: A5 Module, Installation scenario data for 1 m^2 of installed white SPPR PVC roofing membrane (40, 48, 60 and 80 mils)

Declared membrane	Units	Quantity
Fasteners (5" type screws and seam plates)[1)]	kg	0.111
Electricity for seam welding	kWh	0.021
Electricity for securing the screws	kWh	0.015
Seam area	m^2	0.05
Material loss	m^2	0.01
Waste transport to landfill (including packaging waste)– one way	mi/km	20/32

Notes:

1) Each fastener is typically used to hold down 7.5 sq. ft. (0.7 m^2) of PVC roofing membrane, so a fastener usage of 1.5 fasteners per m^2 (=10.76/7.5) is used in the LCA. There are 14 screws per pound (5" type). There are 11 seam plates per pound.

Table 6: C1 to C4 Modules, EOL scenario data for 1 m² of installed white SPPR PVC roofing membrane (40, 48, 60 and 80 mils)

EOL Stage	Flow	Units	Quantity
C1	Electricity	kWh	0.0024
	Diesel	MJ	0.421
C2	Discarded PVC membrane	mi/km	20/32
C3	Secondary material[1)]	%	30
C4	Disposal of waste	%	70

Notes:
[1)] Secondary material is either recycled back after processing (e.g. pelletization, grinding etc.) to the PVC roofing system or other PVC products (commercial PVC flooring, PVC expansion joint material for the concrete industry).

Table 7: Optional Module D, Supplementary data for 1 m² of installed white SPPR PVC roofing membrane (40, 48, 60 and 80 mils)

Membrane thickness	Net output flow	Units	Quantity
40 mils	Secondary material	kg	0.37
48 mils	Secondary material	kg	0.46
60 mils	Secondary material	kg	0.56
80 mils	Secondary material	kg	0.77

Notes:
[1)] Secondary post-consumer PVC pellets are assumed functionally equivalent with primary PVC resin.

5 LIFE CYCLE INVENTORY

5.1 DATA COLLECTION, REPRESENTATIVENESS, SOURCES, AND CALCULATIONS

Data collection was based on an initial survey of all CFFA member facility operations for the reference year 2018. CFFA members operate 5 facilities in the USA and Canada producing various PVC roofing membranes. Some facilities are 100% dedicated to the production of SPPR PVC roofing membranes while others may produce other PVC products. In total 6 facilities operated by the 6 CFFA company members (Canadian General-Tower Limited, Carlisle SynTec Systems, Duro-Last Roofing, Inc., FiberTite Roofing Systems, Flex Membrane International Corp., and Sika Corporation-Roofing) completed LCI data collection questionnaires to support the development of this LCA Project Report. Combined their annual production represents over 85% of North American production of single-ply polyester reinforced PVC roofing membranes.

Source of data is specified as: *Direct*, based on measurements or purchasing/selling records of the surveyed facilities; *Indirect*, based on calculations made by the personnel of the surveyed facilities; and *Estimated*, based on the industry average data and/or expert judgment.

Per NSF PCR, Section 5.3 [6] and ISO 21930, 5.3 [3], all facility specific LCI data were weighted based on total annual production to calculate the weighted average LCI profile for SPPR PVC roofing membranes (per m^2).

Data calculation procedures follow ISO 14044 [4], and NSF PCR for Single Ply Roofing Membranes [6]. Per ISO 21930, 7.2.2 [3], when transforming the inputs and outputs of combustible material into inputs and outputs of energy, the net calorific value (lower heating value) of fuels is applied according to scientifically based and accepted values specific to the combustible material.

5.2 DATA QUALITY REQUIREMENTS AND ASSESSMENTS

A detailed description of collected data and the data quality assessment regarding the NSF PCR requirements [6] and ISO 14044 [4] is provided in the LCA project report. Data quality is assessed based on its representativeness (technology coverage, geographic coverage, time coverage), completeness, consistency, reproducibility, transparency and uncertainty (Table 3).

Table 8 Data Quality Requirements and Assessments

Data Quality Requirements	Description
Technology Coverage	Data represents the prevailing technology in use in U.S. and Canada. Whenever available, for all upstream and core material and processes, North American typical or average industry LCI datasets were utilized. *Technological representativeness is characterized as "high".*
Geographic Coverage	The geographic region considered is U.S. and Canada. The geographic coverage of all LCI databases and datasets is given in the project report. *Geographical representativeness is characterized as "high".*
Time Coverage	Activity data are representative as of 2018. - SPPR PVC roofing membrane manufacturing process- primary data collected from 6 facilities: reference year 2018 (12 months); - In-bound/ out-bound transportation data- primary data collected from 6 facilities: reference year 2018 (12 months); - Polyester scrim reinforcement production- primary data were also provided from one CFFA member plant for the reference year 2010 (12 months); - Generic data: the most appropriate LCI datasets were used as found in the US LCI Database, ecoinvent v.3.5 database for US, Canada and global, 2018. US LCI database "dummies" (empty/missing LCI datasets) are substituted with ecoinvent v3.5 LCI datasets. *Temporal representativeness is characterized as "medium" to "high".*
Completeness	All relevant, specific processes, including inputs (raw materials, energy and ancillary materials) and outputs (emissions and production volume) were considered and modeled to provide an industry average for white SPPR PVC roofing membranes (40, 48, 60, and 80 mils). The relevant background materials and processes were taken from the US LCI Database (adjusted for known data placeholders), ecoinvent v 3.5 LCI database for US and Canada, and modeled in SimaPro software v.9.0.0.30, 2019. The completeness of the cradle-to-gate with options process chain in terms of process steps is rigorously assessed for all four membranes.

Data Quality Requirements	Description
Consistency	To ensure consistency, the LCI modeling of the production weighted input and output LCI data for the SPPR PVC roofing membranes used the same LCI modeling structure across the selected CFFA member facilities, which consisted of input raw, secondary, ancillary and packaging materials, intermediate products, energy flows, water resource inputs, product outputs, co-products, by-products, emissions to air, water and soil, and solid and liquid waste disposal. Crosschecks concerning the plausibility of mass and energy flows were continuously conducted. The LCA team conducted mass and energy balances at the facility level and selected process levels to maintain a high level of consistency.
Reproducibility	Internal reproducibility is possible since the data and the models are stored and available in *Athena CFFA LCI database* developed in SimaPro, 2019. A high level of transparency is provided throughout the report as the weighted average LCI profile is presented for each of the declared products as well as major upstream inputs. Key primary (manufacturer specific) and secondary (generic) LCI data sources are summarized in the project report. External reproducibility is also possible as a high level of transparency is provided throughout the Project Report where the LCI data and sources are also summarized.
Transparency	Activity and LCI datasets are transparently disclosed in the project report, including data sources.
Uncertainty	A *sensitivity check* was conducted to assess the reliability of the EPD results and conclusions by determining how they are affected by uncertainties in the data or assumptions on calculation of LCIA and energy indicator results. The sensitivity check includes the results of the *sensitivity analysis* and *Monte Carlo uncertainty analysis.*

5.3 ALLOCATION RULES

Per NSF PCR, Section 7.2 [6], allocation, if required, shall follow the requirements and guidance of ISO 14044:2006, Section 4.3.4 and ISO 21930, Section 7.2.5.

The CFFA SPPR PVC roofing membrane manufacturing facilities produce other co-products besides selected membranes and as such allocation based on the mass of membrane products was necessary. Per ISO 21930, 3 [3], co-product is defined as any of one or more products from the same unit process, but which is not the object of the assessment. As a result, plant specific generic formulations for 1 m^2 of the four membrane products of interest were used to model and calculate the required input raw materials (both primary and secondary), polyester scrim reinforcement, and additives.

“Mass” was used as the physical parameter for allocating flows between the products of interest and other co-products to calculate the input energy flows (electricity, natural gas, propane, etc.), shipping and packaging materials, lubricants, hydraulic fluid, greases, and heating oil, total water consumption, process emissions to air and waste flows.

Per ISO 21930, 3 [3], by-product is defined as co-product from a process that is incidental or not intentionally produced and which cannot be avoided. No burden is allocated to the by-product

of the selected product system such as off-spec PVC roofing membranes- see Figure 3. In addition, allocation related to transport is based on the mass of transported inputs and outputs.

5.4 CUT OFF RULES

The cut-off criteria as per NSF PCR, Section 7.1.6 [6] and ISO 21930, 7.1.8 [3] were followed. Per ISO 21930, 7.1.8 [3], all input/output data required were collected and included in the LCI modelling. No substances with hazardous and toxic properties that pose a concern for human health and/or the environment were identified in the framework of this EPD. Any plant specific data gaps for the reference year 2018 e.g. input hydraulic fluids, lubricants, greases or heated oil, were filled in with plant generic data from previous years or industry average data. Material Safety Data Sheet (MSDSs) were confidentially provided by CFFA plants per each additive e.g. plasticizer, fire retardant, stabilizer, etc. Any data gaps in the MSDS are filled in with two (proxy) generic LCI datasets, as appropriate (conservative assumptions): Chemical, organic {GLO}| production | Cut-off, U; Chemical, inorganic {GLO}| production | Cut-off, U- see Annex B, Table B1 for details.

This EPD *excludes* the following processes:

- Capital goods and infrastructure;
- Human activity and personnel related activity (travel, furniture, office operations and supplies);
- Energy and water use related to company management and sales activities that may be located either within the factory site or at another location.

6 LIFE CYCLE ASSESSMENT

6.1 RESULTS OF THE LIFE CYCLE ASSESSMENT

This section summarizes the life cycle impact assessment (LCIA) results including resource use and waste generated metrics based on the cradle-to-gate with options life cycle inventory inputs and outputs analysis. The results are calculated based on 1 m^2 installed of white SPPR PVC roofing membranes (40, 48, 60 and 80 mils)- see Tables 9 to 12. *It should be noted that LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks [4], [5].*

Per NSF PCR, Section 7.3 [6], the US EPA Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI), version 2.1, 2012 impact categories are used as they provide a North American context for the mandatory category indicators to be included in this EPD. Per NSF PCR, Section 9.5 [6], the following mandatory resource use, waste categories and output flows are reported as described in Tables 9 to 12.

Table 9 Cradle-to-construction with EOL stage (A1-A5, C1 to C4, D), EPD Results – 1 m² of white SPPR PVC roofing membrane (40 mils)

Impact category and inventory indicators	Unit	A1-A3	A4	A5	C1-C4	D
Global warming potential, GWP 100[1)]	kg CO_2 eq	4.2	0.11	0.51	0.10	-0.7
Ozone depletion potential, ODP[1)]	kg CFC-11 eq	5.5E-07	4.8E-12	5.1E-08	9.3E-09	-9.7E-08
Smog formation potential, SFP[1)]	kg O_3 eq	0.25	0.039	0.032	0.013	-0.011
Acidification potential, AP[1)]	kg SO_2 eq	0.023	0.0015	0.0025	0.0005	-0.0022
Eutrophication potential, EP[1)]	kg N eq	0.061	0.0001	0.005	0.007	-0.0013
Fossil fuel depletion, FFD[1)]	MJ surplus	8.5	0.24	0.66	0.09	-2.3
Abiotic depletion potential, fossil ADPf[2)]	MJ LHV	66.2	1.6	6.6	0.6	-16.2
Renewable primary resources used as an energy carrier (fuel), RPR_E	MJ LHV	3.8	0	0.32	0.0039	-1.6E-01
Renewable primary resources with energy content used as material, RPR_M[3)]	MJ LHV	-[6)]	-	-	-	-
Non-renewable primary resources used as an energy carrier (fuel), $NRPR_E$	MJ LHV	48.9	1.6	7.1	0.6	-17.0
Non-renewable primary resources with energy content used as material, $NRPR_M$[3)]	MJ LHV	26.8	0	0.27	0	0
Secondary materials, SM[3)]	kg	0.019	0	0.0011	0	0
Renewable secondary fuels, RSF[3)]	MJ LHV	-	-	-	-	-
Non-renewable secondary fuels, NRSF[3)]	MJ LHV	-	-	-	-	-
Recovered energy, RE[3)]	MJ LHV	-	-	-	-	-
Consumption of freshwater, FW[3)]	m^3	6.7E-04	0	4.0E-05	0	0
Hazardous waste disposed, HWD[3)]	kg	3.3E-03	0	2.0E-04	0	0
Non-hazardous waste disposed, NHWD[3)]	kg	0.022	0	0.0013	0	0
High-level radioactive waste, conditioned, to final repository, HLRW[3) 4)]	m^3	5.8E-09	0	4.9E-10	8.7E-12	-4.9E-10
Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW[3) 5)]	m^3	6.8E-08	0	7.9E-09	3.2E-09	-5.9E-09

Impact category and inventory indicators	Unit	A1-A3	A4	A5	C1-C4	D
Components for re-use, CRU[3)]	kg	-	-	-	-	-
Materials for recycling, MR[3)]	kg	0.022	0	0.001	0.359	0
Materials for energy recovery, MER[3)]	kg	-	-	-	-	-
Recovered energy exported from the product system, EE[3)]	MJ LHV	-	-	-	-	-

Table 10 Cradle-to-construction with EOL stage (A1-A5, C1 to C4, D), EPD Results – 1 m² of white SPPR PVC roofing membrane (48 mils)

Impact category and inventory indicators	Unit	A1-A3	A4	A5	C1-C4	D
Global warming potential, GWP 100[1)]	kg CO_2 eq	5.2	0.15	0.57	0.11	-0.8
Ozone depletion potential, ODP[1)]	kg CFC-11 eq	7.1E-07	6.1E-12	6.0E-08	9.4E-09	-1.2E-07
Smog formation potential, SFP[1)]	kg O_3 eq	0.31	0.050	0.037	0.013	-0.014
Acidification potential, AP[1)]	kg SO_2 eq	0.029	0.0019	0.0028	0.0006	-0.0028
Eutrophication potential, EP[1)]	kg N eq	0.076	0.0001	0.006	0.009	-0.0016
Fossil fuel depletion, FFD[1)]	MJ surplus	10.7	0.31	0.79	0.09	-2.9
Abiotic depletion potential, fossil ADPf[2)]	MJ LHV	82.5	2.1	7.6	0.6	-20.1
Renewable primary resources used as an energy carrier (fuel), RPR_E	MJ LHV	4.8	0	0.38	0.0043	-2.0E-01
Renewable primary resources with energy content used as material, RPR_M[3)]	MJ LHV	-[6)]	-	-	-	-
Non-renewable primary resources used as an energy carrier (fuel), $NRPR_E$	MJ LHV	60.0	2.1	8.1	0.7	-21.2
Non-renewable primary resources with energy content used as material, $NRPR_M$[3)]	MJ LHV	34.2	0	0.34	0	0
Secondary materials, SM[3)]	kg	0.030	0	0.0018	0	0
Renewable secondary fuels, RSF[3)]	MJ LHV	-	-	-	-	-
Non-renewable secondary fuels, NRSF[3)]	MJ LHV	-	-	-	-	-
Recovered energy, RE[3)]	MJ LHV	-	-	-	-	-

Impact category and inventory indicators	Unit	A1-A3	A4	A5	C1-C4	D
Consumption of freshwater, FW[3)]	m^3	8.5E-04	0	5.1E-05	0	0
Hazardous waste disposed, HWD[3)]	kg	4.1E-03	0	2.5E-04	0	0
Non-hazardous waste disposed, NHWD[3)]	kg	0.026	0	0.0016	0	0
High-level radioactive waste, conditioned, to final repository, HLRW[3) 4)]	m^3	7.0E-09	0	5.7E-10	9.6E-12	-6.0E-10
Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW[3) 5)]	m^3	8.4E-08	0	8.8E-09	3.2E-09	-7.4E-09
Components for re-use, CRU[3)]	kg	-	-	-	-	-
Materials for recycling, MR[3)]	kg	0.027	0	0.002	0.463	0
Materials for energy recovery, MER[3)]	kg	-	-	-	-	-
Recovered energy exported from the product system, EE[3)]	MJ LHV	-	-	-	-	-

Table 11 Cradle-to-construction with EOL stage (A1-A5, C1 to C4, D), EPD Results – 1 m² of white SPPR PVC roofing membrane (60 mils)

Impact category and inventory indicators	Unit	A1-A3	A4	A5	C1-C4	D
Global warming potential, GWP 100[1)]	kg CO_2 eq	6.3	0.18	0.65	0.13	-1.0
Ozone depletion potential, ODP[1)]	kg CFC-11 eq	8.9E-07	7.4E-12	7.1E-08	9.4E-09	-1.5E-07
Smog formation potential, SFP[1)]	kg O_3 eq	0.39	0.060	0.042	0.013	-0.016
Acidification potential, AP[1)]	kg SO_2 eq	0.035	0.0023	0.0032	0.0007	-0.0034
Eutrophication potential, EP[1)]	kg N eq	0.099	0.0001	0.007	0.011	-0.0020
Fossil fuel depletion, FFD[1)]	MJ surplus	13.0	0.37	0.93	0.10	-3.5
Abiotic depletion potential, fossil ADPf[2)]	MJ LHV	100.4	2.5	8.7	0.7	-24.5
Renewable primary resources used as an energy carrier (fuel), RPR_E	MJ LHV	5.9	0	0.45	0.0047	-2.4E-01
Renewable primary resources with energy content used as material, RPR_M[3)]	MJ LHV	-[6)]	-	-	-	-
Non-renewable primary resources used as an energy carrier (fuel), $NRPR_E$	MJ LHV	72.1	2.5	9.3	0.7	-25.8
Non-renewable primary resources with energy content used as material, $NRPR_M$[3)]	MJ LHV	42.2	0	0.42	0	0
Secondary materials, SM[3)]	kg	0.041	0	0.0024	0	0
Renewable secondary fuels, RSF[3)]	MJ LHV	-	-	-	-	-
Non-renewable secondary fuels, NRSF[3)]	MJ LHV	-	-	-	-	-
Recovered energy, RE[3)]	MJ LHV	-	-	-	-	-
Consumption of freshwater, FW[3)]	m^3	1.1E-03	0	6.4E-05	0	0
Hazardous waste disposed, HWD[3)]	kg	5.2E-03	0	3.1E-04	0	0
Non-hazardous waste disposed, NHWD[3)]	kg	0.061	0	0.0037	0	0
High-level radioactive waste, conditioned, to final repository, HLRW[3) 4)]	m^3	8.5E-09	0	6.6E-10	1.1E-11	-7.4E-10
Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW[3) 5)]	m^3	1.0E-07	0	9.9E-09	3.2E-09	-9.0E-09

Impact category and inventory indicators	Unit	A1-A3	A4	A5	C1-C4	D
Components for re-use, CRU[3)]	kg	-	-	-	-	-
Materials for recycling, MR[3)]	kg	0.033	0	0.002	0.566	0
Materials for energy recovery, MER[3)]	kg	-	-	-	-	-
Recovered energy exported from the product system, EE[3)]	MJ LHV	-	-	-	-	-

Table 12 Cradle-to-construction with EOL stage (A1-A5, C1 to C4, D), EPD Results – 1 m² of white SPPR PVC roofing membrane (80 mils)

Impact category and inventory indicators	Unit	A1-A3	A4	A5	C1-C4	D
Global warming potential, GWP 100[1)]	kg CO_2 eq	8.3	0.24	0.77	0.16	-1.4
Ozone depletion potential, ODP[1)]	kg CFC-11 eq	1.2E-06	1.0E-11	9.1E-08	9.5E-09	-2.0E-07
Smog formation potential, SFP[1)]	kg O_3 eq	0.48	0.082	0.049	0.014	-0.023
Acidification potential, AP[1)]	kg SO_2 eq	0.044	0.0032	0.0038	0.0008	-0.0046
Eutrophication potential, EP[1)]	kg N eq	0.109	0.0002	0.008	0.014	-0.0027
Fossil fuel depletion, FFD[1)]	MJ surplus	17.4	0.51	1.20	0.10	-4.8
Abiotic depletion potential, fossil ADPf[2)]	MJ LHV	132.6	3.4	10.7	0.7	-33.7
Renewable primary resources used as an energy carrier (fuel), RPR_E	MJ LHV	8.2	0	0.59	0.0055	-3.3E-01
Renewable primary resources with energy content used as material, RPR_M[3)]	MJ LHV	-[6)]	-	-	-	-
Non-renewable primary resources used as an energy carrier (fuel), $NRPR_E$	MJ LHV	93.4	3.5	11.4	0.7	-35.4
Non-renewable primary resources with energy content used as material, $NRPR_M$[3)]	MJ LHV	57.5	0	0.58	0	0
Secondary materials, SM[3)]	kg	0.143	0	0.0086	0	0
Renewable secondary fuels, RSF[3)]	MJ LHV	-	-	-	-	-
Non-renewable secondary fuels, NRSF[3)]	MJ LHV	-	-	-	-	-
Recovered energy, RE[3)]	MJ LHV	-	-	-	-	-

Impact category and inventory indicators	Unit	A1-A3	A4	A5	C1-C4	D
Consumption of freshwater, FW[3)]	m^3	1.4E-03	0	8.6E-05	0	0
Hazardous waste disposed, HWD[3)]	kg	6.9E-03	0	4.1E-04	0	0
Non-hazardous waste disposed, NHWD[3)]	kg	0.080	0	0.0048	0	0
High-level radioactive waste, conditioned, to final repository, HLRW[3) 4)]	m^3	1.1E-08	0	8.2E-10	1.2E-11	-1.0E-09
Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW[3) 5)]	m^3	1.3E-07	0	1.2E-08	3.2E-09	-1.2E-08
Components for re-use, CRU[3)]	kg	-	-	-	-	-
Materials for recycling, MR[15)]	kg	0.131	0	0.008	0.775	0
Materials for energy recovery, MER[3)]	kg	-	-	-	-	-
Recovered energy exported from the product system, EE[3)]	MJ LHV	-	-	-	-	-

Notes to Tables 9 to 12:

[1)] Calculated as per U.S EPA TRACI 2.1, v1.05, SimaPro v 9. GWP-100, excludes biogenic CO_2 removals and emissions associated with any biobased products; 100-year time horizon GWP factors are provided by the IPCC 2013 Fifth Assessment Report (AR5), TRACI 2.1, v1.05 [10]. FFD is required in LEED V4.1 MR Credit: Building Product Disclosure and Optimization – Environmental Product Declarations [11].

[2)] Calculated as per CML-IA Baseline V3.05, SimaPro v 9. ADP_f is also required in LEED V4.1 MR Credit: Building Product Disclosure and Optimization – Environmental Product Declarations [11].

[3)] Calculated as per ACLCA ISO 21930 Guidance [12], respective sections 6.2 to 10.8.

[4)] It should be noted that the foreground system (SPPR PVC roofing membrane manufacturing process) does not generate any HLRW. High-level radioactive waste, e.g., when generated by electricity production, consists mostly of spent fuel from reactors." (ISO 21930:2017, clause 7.2.14).

[5)] It should be noted that the foreground system (SPPR PVC roofing membrane manufacturing process) does not generate any ILLRW. Low- and intermediate-level radioactive wastes, e.g., when generated by electricity production, arise mainly from routine facility maintenance and operations (ISO 21930:2017, clause 7.2.14).

[6)] "-"N/A for this product system. "*Not all LCA datasets for upstream materials include these impact categories and thus results may be incomplete. Use caution when interpreting data in these categories" [6]*.

[7)] "*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*: RPR_E, RPR_M, $NRPR_E$, $NRPR_M$, SM, RSF, NRSF, RE, HWD, NHWD, HLRW, ILLRW, CRU, MR, MER, EE" [6].

[8)] Biogenic C-content of packaging fall below the cut-off criteria (NSF PCR, Section 7.1.6 [6] and ISO 21930, 7.1.8 [3]), and is therefore excluded. It should be noted that GWP based in biogenic C-content of packaging is not included in the quantification of GWP 100.

6.2 INTERPRETATION

Figures 4 to 7 present the impact assessment and energy indicator results for 1 m^2 of white SPPR PVC roofing membranes (40, 48, 60 and 80 mils), by stage on a percent contribution basis.

For each of the declared membrane thicknesses, the *Production stage* (A1 to A3) dominates the LCIA and energy indicator results – ranging from 75% to 93% of the total potential impacts. Except for SFP (21%), the *Construction stage* (A4 to A5) accounted for less than 14% of the total potential impacts. The *End-of-life stage* (C1 to C4) was generally found to be a minor contributor to the declared product potential impacts; however, it did account for about 10% of the eutrophication potential, as a result of waste disposal.

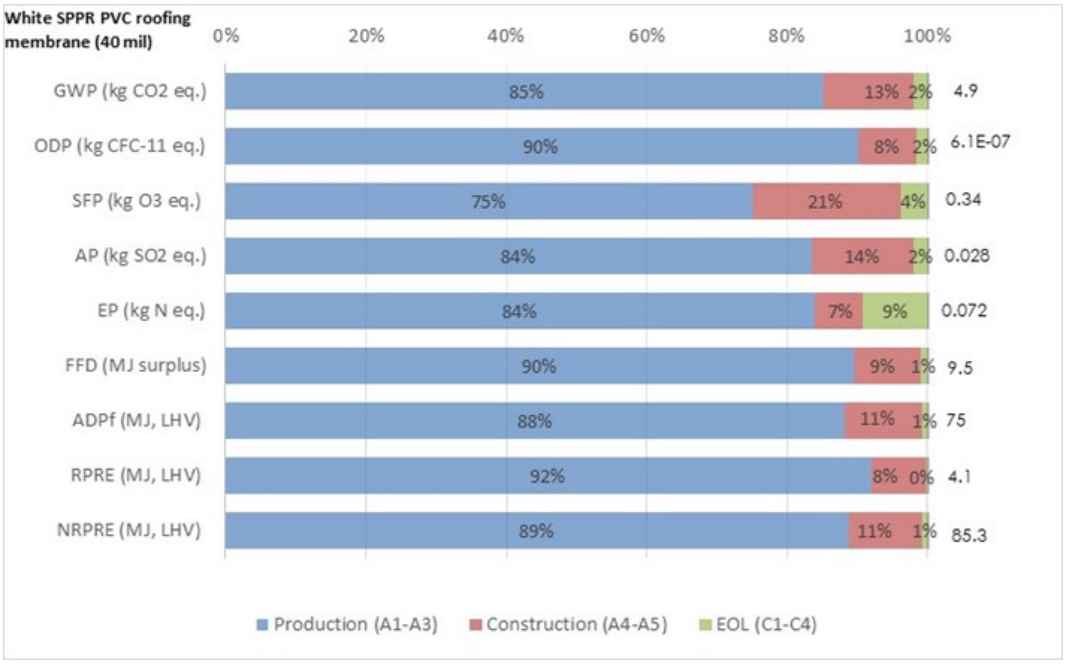


Figure 4 Impact assessment and energy indicator results by stage – 1 m^2 of 40 mils white SPPR PVC roofing membrane – % Basis

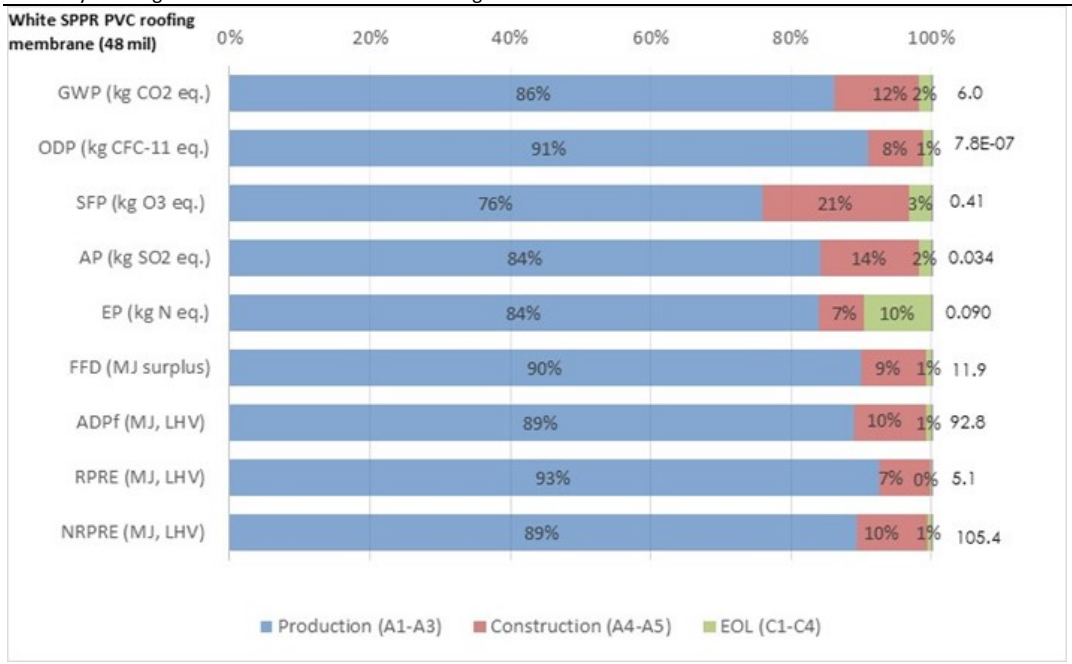


Figure 5 Impact assessment and energy indicator results by stage – 1 m^2 of 48 mils white SPPR PVC roofing membrane – % Basis

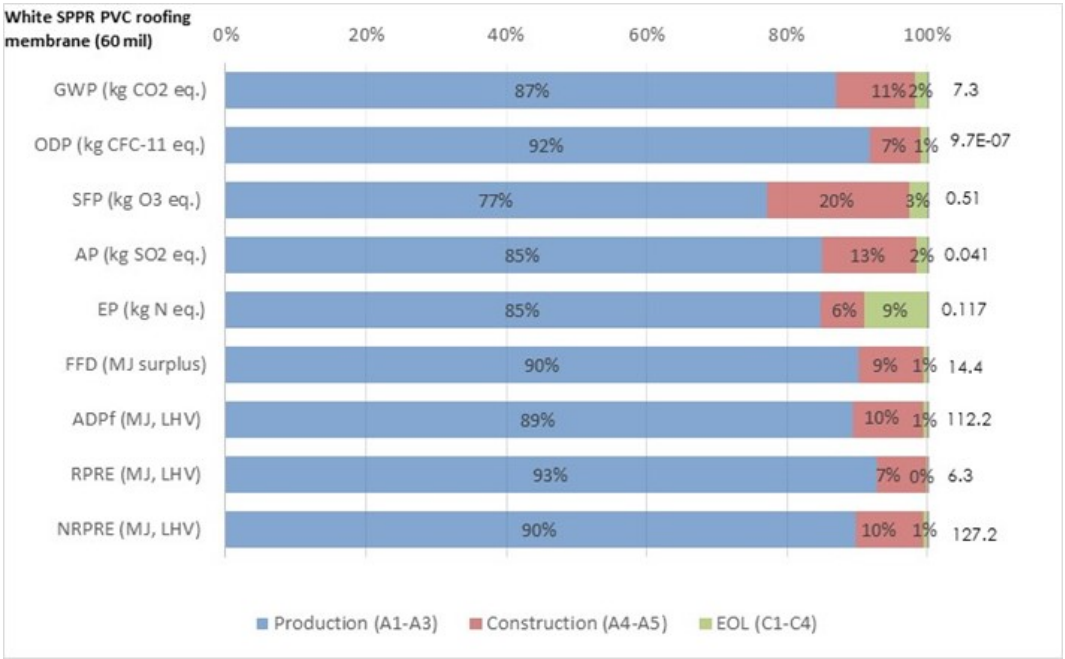


Figure 6 Impact assessment and energy indicator results by stage – 1 m^2 of 60 mils white SPPR PVC roofing membrane – % Basis

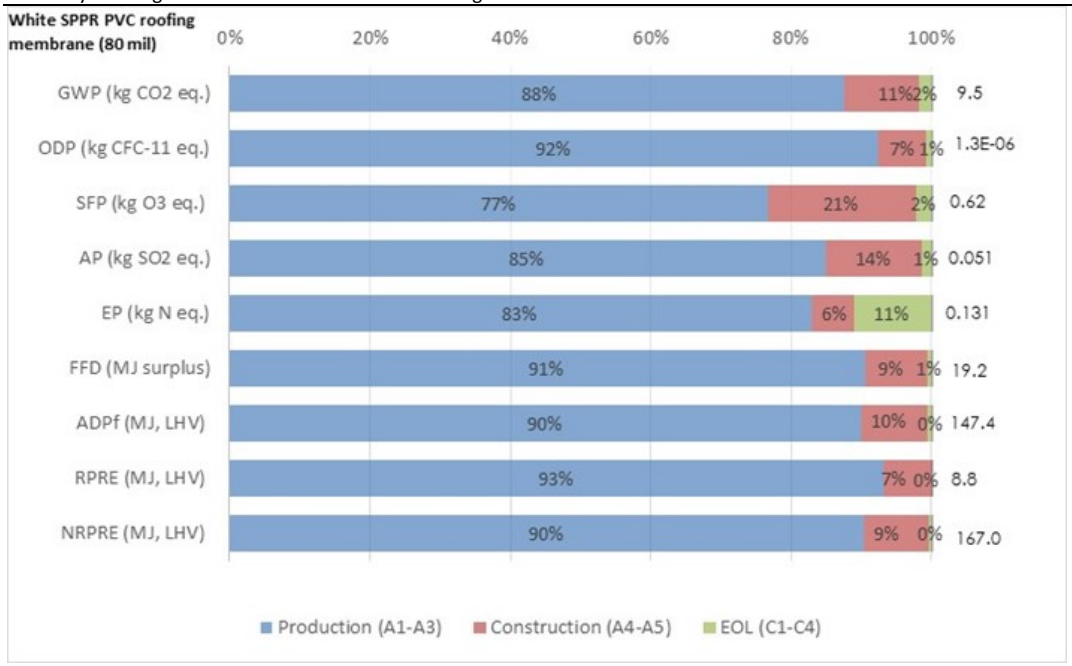


Figure 7 Impact assessment and energy indicator results by stage – 1 m² of 80 mils white SPPR PVC roofing membrane – % Basis

7 ADDITIONAL ENVIRONMENTAL INFORMATION

- *Cool Roofing*

  The four declared membrane thicknesses meet or exceed the cool roofing requirements of USGBC's LEED program, Green Globes, ENERGY STAR and California Title 24.

- *Health Protection Manufacture*

  The OSHA standards are applicable and followed.

  - U.S. Department of Labor, Occupational Safety & Health Administration (OSHA), 29 CFR, PART 1910 Occupational Safety and Health Standards. https://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=1&p_keyvalue=1910, accessed 21-11-2019.

  No additional health protection measures extending beyond mandatory occupational safety measures for commercial operations are required.

- *Environmental Protection Manufacture and Equipment*

  The CFFA member manufacturing facilities comply with the regional (US and Canadian) environmental protection requirements, monitor and report the emissions to air during the manufacturing process as per the following:

- EPCRA Section 313 Toxic Release Inventory Reporting (U.S) https://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=1&p_keyvalue=1910, accessed 21-11-2019.

- The Canadian National Pollutant Release Inventory (NPRI) reporting http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=4A577BB9-1, accessed 21-11-2019.

Pollution abatement equipment typically used in the CFFA manufacturing facilities consist of Regenerative Thermo Oxidizer (RTO)– without energy recovery, fabric filter– high efficiency air filtration, and electrostatic precipitator.

- *No substances of high concern were identified in the framework of this EPD.*

8 DECLARATION TYPE AND PRODUCT AVERAGE DECLARATION

The type of EPD is defined as:

- An industry average "Cradle-to-building with EOL stage" EPD of four selected white SPPR PVC roofing membrane thicknesses (40, 48, 60 and 80 mils) covering the production, construction and EOL stages (modules A1 to A5 and C1 to C4) and is intended for use in Business to Business communication.

CFFA EPD falls under the description:

- An average product EPD, as an average from several CFFA PVC roofing membrane manufacturers' facilities (in this case, CFFA member manufacturers as listed under "CFFA Member Companies Corporate Locations", *see General Summary section*).

9 DECLARATION COMPARABILITY LIMITATION STATEMENT

The following ISO 21930 statements indicate the EPD comparability limitations and intent to avoid any market distortions or misinterpretation of EPDs based on the NSF PCR for Single Ply Roofing Membranes [6]:

Only EPDs prepared from cradle-to-grave life cycle results and based on the same function, RSL, quantified by the same functional unit, and meeting all the conditions for comparability listed in ISO 14025:2006 and ISO 21930:2017 can be used to comparison between products. No claim of environmental superiority may be inferred or implied from cradle-to-gate EPDS.

11 REFERENCES

1. ASTM D4434/ D4434M – 15 Standard Specification for Poly(Vinyl Chloride) Sheet Roofing.
2. ASTM D6754/ D6754M – 15 Standard Specification for Ketone Ethylene Ester Based Sheet Roofing.
3. ISO 21930:2017 Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services.
4. ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework.
5. ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines.
6 NSF International, Product Category Rule Environmental Product Declarations, PCR for Single Ply Roofing Membrane, October 2019. https://www.spri.org/wpfb-file/pcr-single-ply-roofing-membrane-2019-pdf/, accessed 21-11-2019.
7 ASTM Program Operator for Product Category Rules (PCRs) and Environmental Product Declarations (EPDs), General Program Instructions, 12/5/2014.
8. ISO 14025:2006 Environmental labeling and declarations - Type III environmental declarations - Principles and procedures.
9. ISO 14021:2016 Environmental labels and declarations -- Self-declared environmental claims (Type II environmental labelling).
10. PRé 2019.SimaPro LCA Software v9.0.0.30, 2019. https://simapro.com/, accessed 04-09-2019.
11. LEED v4.1 July 2019, Building Design and Construction Guide (BD+C), Getting started guide for beta participant, MR Credit: Building Product Disclosure and Optimization – Environmental Product Declarations. https://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-162, accessed 21-11-2019.
12. ACLCA Guidance to Calculating Non-LCIA Inventory Metrics in Accordance with ISO 21930:2017. The American Centre for Life Cycle Assessment. May, 2019. https://aclca.org/aclca-iso-21930-guidance/, https://aclca.org/wp-content/uploads/ISO-21930-Final.pdf, accessed 21-11-2019.
16. Athena Sustainable Materials Institute 2019, *A Cradle-to-Building with EOL stage Life Cycle Assessment for Four Thicknesses of White, Single-Ply Polyester Reinforced PVC Roofing Membrane (40, 48, 60 and 80 mils),* Final Report, Prepared for CFFA. February 2020.