Environmental Product Declaration

According to ISO 14025

Spray Polyurethane Foam Insulation (HFO)

Use of this EPD is limited to SPFA members.

Issue Date: 10-29-2018

Valid Until: 10-29-2023

Declaration Number: EPD-085

Declaration Information

Declaration

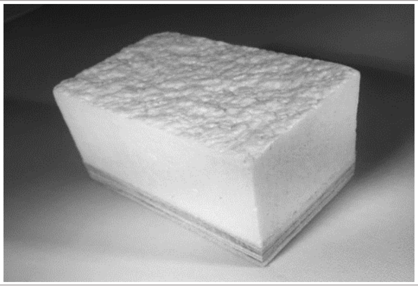
Program Operator: ASTM International	www.astm.org	www.sprayfoam.org
Company: Spray Polyurethane Foam Association (SPFA)		

Product Information	Validity / Applicability
Product Name: Spray polyurethane foam insulation (HFO) **Product Definition:** Two-component polyurethane mixture insulation spray applied at installation site.	**Period of Validity:** This declaration is valid for a period of 5 years from the date of publication
Declaration Type: Business to business	**Geographic Scope:** This declaration is valid for foam produced and sold in the United States and Canada.
PCR Reference: – ISO 21930 (ISO, 2017) – Part A: Product Category Rules for Building Related Products and Services (UL Environment, 2018) – Part B: Building Envelope Thermal Insulation EPD Requirements (UL Environment, 2018)	**PCR Review was conducted by:** – Part A – UL Technical Advisory Panel – Part B – Thomas Gloria, PhD (chair)

Product Application and / or Characteristics

This declaration covers spray polyurethane foam insulation used in buildings and construction.

Technical Drawing or Product Visual



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
- Data on usage condition, other effects and end-of-life phase
- Life Cycle Assessment results

Verification

Independent verification of the declaration and data, according to ISO 21930:2017 and ISO 14025:2006:	☐ internal x external
This declaration and the rules on which this EPD is based have been examined by an independent verifier in accordance with ISO 14025.	

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EPD Summary

This document is a Type III environmental product declaration by Spray Polyurethane Foam Association (SPFA) 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 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. Comparison of the environmental performance of construction works and construction products using EPD information shall be based on the product's use and impacts at the construction works level. 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. 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, 2006) and ISO 14044 (ISO, 2006) following the requirements of the ASTM EPD Program Instructions and referenced PCR.

System Boundary: Cradle-to-grave
Allocation Method: Cut-off approach
Declared Unit: 1 m² of installed insulation material with a thickness that gives an average thermal resistance RSI=1 $m^2 \cdot K/W$

Additional Information

All types of spray polyurethane foam provide insulation (R-value) and air sealing (air-impermeable) when installed at normal thickness in a building enclosure. Additionally, closed-cell and roofing SPF products can serve as a vapor retarder (moisture impermeable), are water resistant for below-grade applications[1] and meet the FEMA Class 5 requirements[2] for flood-damage resistant insulation materials for floors and walls, and can improve the structural integrity of many building assemblies. The high R-value per inch of closed-cell SPF insulation can also reduce assembly thickness and framing materials. These factors should be considered when comparing SPF to similar products.

[1] According to the ASTM C1029 material standard specification, all closed-cell SPF must have a maximum water absorption limit of 5.0% per ASTM D2842. Several Type I and II medium density closed-cell foams have been tested for water absorption per ASTM C1763 Method C (ASTM C272) and have water absorption rates ranging from 0,21 to 0.38%. Many of these products tested meet the 0.3% water absorption maximum per ASTM C272 prescribed for below-grade exterior insulations per ASHRAE 90.1.

[2] "Flood Damage-Resistant Materials Requirements", FEMA Technical Bulletin 2, 2008, Table 2.

1 Organization, Product, and Product Category Descriptions

1.1 | DESCRIPTION OF COMPANY/ORGANIZATION

Founded in 1987 originally as the Polyurethane Foam Contractors Division, the Spray Polyurethane Foam Alliance (SPFA) is the collective voice, along with the educational and technical resource, for the spray polyurethane foam industry. Our experienced staff and member-comprised committees provide a wide variety of services to the industry.

SPFA develops tools designed to educate and influence the construction industry with the positive benefits of spray polyurethane foam roofing, insulation, coatings, and specialty installations.

This project was funded by contributions from sixteen SPFA supplier member companies in the SPF industry. Twelve of these sponsors produce or formulate spray foam systems throughout the US and Canada. SPF producers that contributed to this declaration are featured below. In addition, the other four sponsors produce chemical components used in the formulation of SPF products or equipment used to mix and install SPF on the jobsite.

SPF Formulator Sponsors:

SPF Chemical and Equipment Supplier Sponsors:

1.2 | DESCRIPTION AND DEFINITION OF PRODUCTS

Spray polyurethane foam (SPF) is made on the jobsite by combining polymeric methylene-diphenyl diisocyanate (pMDI/MDI or A-side) with an equal volume of a polyol blend (B-side). Sides A and B react and expand at the point of application in the building envelope to form polyurethane foam. The formed-in-place SPF provides both thermal insulation and air sealing to the building.

Figure 1: Visual of high pressure products under study

Four classes of SPF with varying performances and applications are assessed in this declaration. Closed-cell spray foam for roofing systems (Roofing) is used on the external surface of low slope roofs. Its higher density provides additional compressive strength needed for roofing applications. Closed-cell, or medium density foam, (ccSPF) provides a water-resistant insulation, air-sealing, water vapor control and delivers added structural performance to the building envelope. Open-cell low-density spray foam (ocSPF) provides insulation and air sealing.

SPF can be further categorized based on the type of blowing agent utilized in the product. OcSPF uses a reactive blowing agent, water. Added water in the B-side reacts with A-side isocyanates to create CO2 gas. CcSPF and roofing foams use physical blowing agents that transform into a gas during installation due to the exothermic foam reaction that occurs. These physical blowing agents are either hydrofluorocarbons (HFC) or hydrofluoroolefins (HFO). Please note that this declaration only covers HFO formulations for ccSPFand roofing products, as well as reactive (water) blowing agent ocSPF. A complete list of all SPF manufacturers and product covered by this declaration is provided in the Appendix.

SPF products are commonly used in residential, light commercial, commercial, institutional, and certain industrial applications. Typical SPF properties are shown in

Table 1.

Table 1. Typical SPF properties

NAME	ROOFING	CLOSED CELL	OPEN CELL
Density [lb / ft^3]	2.5 to 4.0	1.5 to 2.4	0.5 to 0.7
Thermal resistivity [R / in]	6.2 to 6.8	6.2 to 7.0	3.6 to 4.5
Air impermeable material	✓	✓	✓
Integral vapor retarder	✓	✓	
Water resistant	✓	✓	
Cavity insulation		✓	✓
Continuous insulation	✓	✓	✓
Low-slope roofing	✓		
Structural improvement	✓	✓	

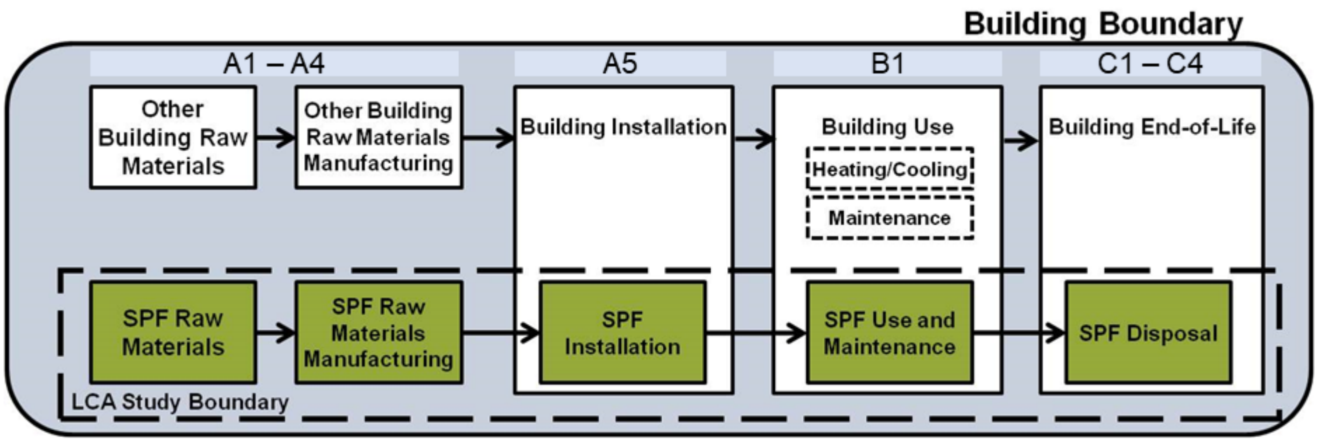


Figure 2. Flow diagram of SPF life cycle

1.3 | PRODUCT USE AND APPLICATION

The EPD is intended to represent an industry average for SPF. The average is calculated based on a typical formulation for each product, combined with production data collected from each member's facility, and weighted according to the mass produced by each member (i.e. vertical averaging). The formulators participating in this study represent a significant majority of the US SPF production.

Open cell products are applied to the interior side of the building envelope as an insulation and air-sealing material. They are used to insulate under roof decks, on attic floors, above-grade walls, and below floors. Closed cell is applied to the interior or exterior side of the building envelope and can be used in the same applications as open cell. Due to its water resistance, it can also be used on below grade walls and under slabs. Roofing SPF is applied to the exterior surface of low-slope roofs. A variety of polymeric coatings are used over Roofing SPF to provide protection against ultraviolet light and mechanical abrasion.

1.4 | TECHNICAL REQUIREMENTS

All SPF products must meet numerous peformance requirments to comply with building codes. The details of these requirements are described in specific tests listed in consensus standards for material performance and code compliance. A summary of these consensus standards is provided in Table 2 below:

Table 2: Summary of Technical Standards for SPF in Construction

Standard Type	Roofing	Closed cell	Open cell
ASTM	ASTM C1029 Type III and IV or ASTM D7425	ASTM C1029 Type I and II	ASTM WK30150
CAN/ULC		S705.1	S712.1
ICC Building Code Compliance	ICC-ES AC-377 ICC-1100 20xx		

ASTM Standards
- C1029-15 Standard Specification for Spray-Applied Rigid Cellular Polyurethane Thermal Insulation
- D7425-13 Standard Specification for Spray Polyurethane Foam Used for Roofing Applications
- WK30150 (under development) Standard Specification for Spray-Applied Open Cellular Polyurethane Thermal Insulation

UL Canada Standards
- S705.1 Standard for Thermal Insulation – Spray Applied Rigid Polyurethane Foam, Medium Density
- S712.1 Standard for Thermal Insulation - Light Density, Open Cell Spray Applied Semi-Rigid Polyurethane Foam

International Code Council Standards
- ICC-ES AC-377 Acceptance Criteria for Spray-Applied Foam Plastic Insulation
- ICC-1100-20xx Standard for Spray-applied Polyurethane Foam Plastic Insulation

Typical material performance requirements per ICC-1100 are provided in Table 3 below.

Table 3: Summary of Typical Material Performance Requirements for SPF in Construction

Standard Type		Roofing	Closed cell	Open cell
Thermal Performance (R-value)	ASTM C518, C177 or C1363	As reported (typ R6.0-7.0/inch / 4.2-4.8/100 mm)	As reported (typ R6.0-7.0/inch / 4.2-4.8/100 mm)	As reported (typ R3.6-4.3/inch / 2.5-3.0/100mm)
Surface Burning Characteristics	ASTM E84 or UL723	Flame spread index ≤ 75	Flame spread index ≤ 75 Smoke developed ≤ 450	Flame spread index ≤ 75 Smoke developed ≤ 450
Core Density	ASTM D1622	As reported (typ 2.5-4.0 pcf / 40-64 kg/m^3)	As reported (typ 1.5-2.5 pcf / 24-40 kg/m^3)	As reported (typ 0.4-1.5 pcf / 6.4-24 kg/m^3)
Closed-Cell Content	ASTM D2856 or ASTM D6226	>90%	>90%	NR
Tensile Strength	ASTM D1623	40 psi min (276 kPa)	15 psi min (103 kPa)	3 psi min (21 kPa)
Compressive Strength	ASTM D1623	40 psi min (276 kPa)	15 psi min (103 kPa)	NR
Dimensional Stability	ASTM D2126	15% max change	15% max change	15% max change
Water Vapor Permeance	ASTM E96 (dry cup)	As reported (typ 1 US perm @ 2" thk / 0.66 SI perm @ 51 mm)	As reported (typ 1 US perm @ 2" thk / 0.66 SI perm @ 51 mm)	NR
Air Permeance	ASTM D E283 or D2178	As reported (typ imperm @ 1.5" thk / 38 mm)	As reported (typ imperm @ 1.5" thk / 38 mm)	As reported (typ imperm @ 3-5" thk / 76-127 mm)
Water Absorption	ASTM D2842	5% max	<5% max	NR

1.5 | PROPERTIES OF DECLARED PRODUCT AS DELIVERED

The two chemicals required to produce SPF are delivered to the job site in separate containers. On the job site, these chemicals are mixed in equal volume proportions to create SPF.

1.6 | MATERIAL CONTENT

The A-side of SPF is made from a blend of polymeric methylene diphenyl diisocyanate (MDI). The B-side is a mixture of polyester and polyether polyols, flame retardants, blowing agents, catalysts, and other additives that, when mixed with A-side, creates foam that can be applied for insulation. As the precise formulation of the B-side will vary with each company producing SPF chemicals, this study uses generic formulations. A total of seven generic formulations were developed by stakeholders from SPFA and the American Chemistry Council's Center for the Polyurethanes Industry (CPI). The compositions of the open-cell SPF and HFC-based closed-cell foams are functional formulations used by CPI to develop emissions and air-sampling protocols and are representative of individual industry formulations. The HFO-based closed-cell formulations were agreed, by sponsor consensus, to use a simple drop-in replacement of the HFC with an HFO. The HFC-based roofing formulation is not a functional foam but was developed by SPFA in 2012 based on a consensus process with several foam manufacturers. The HFO-based roofing foam is identical to the HFC-based foam, replacing the HFC with HFO.

Since one half of the formulation by volume is MDI (A-side), the table focuses on the other multi-component half (B-side) for four representative formulations from SPFA members. The B-side formulations each have their own distinctive characteristics, lending themselves to unique applications.

While some of the ingredients may be classified as hazardous, per the Resource Conservation and Recovery Act (RCRA), Subtitle 3, the product as installed and ultimately disposed of is not classified as a hazardous substance, as hazardous ingredients are rendered chemically inert after installation.

Table 4. Generic HFO B-side formulations

Chemical (% Composition)		Roofing	Closed cell	Open cell
Polyol	Polyester	35	36	-
	Polyether	-	34	34
	Mannich	45	-	-
	Compatibilizer	-	-	12
Fire Retardant	TCPP	8	16	25
Blowing Agent	Reactive (H_2O)	2	3	20
	HFO, aggregate	7	7	-
Catalyst	Catalyst, amine	-	-	8
	Catalyst, metal	1	-	-
	Catalyst, aggregate	1	3	-
Surfactant	Silicone	1	1	1

2 Life Cycle Stages

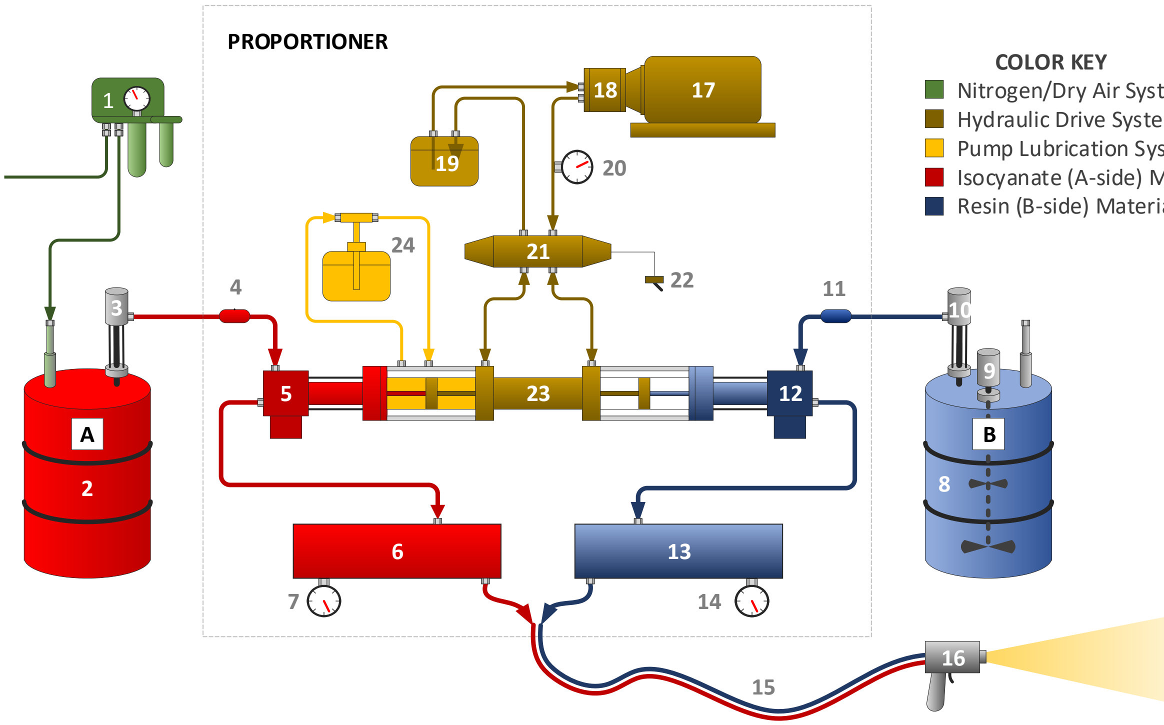
2.1 | PRODUCTION

A significant majority the A-side of SPF is manufactured by four U.S. based chemical manufacturing companies with processing facilities located in Texas and Louisiana. The B-side formulation is made by several formulators or systems houses located throughout the U.S. and Canada. Most of the primary chemicals used in the B-side formulation are processed in facilities in Texas, Louisiana and Virginia.

During the B-side production process, materials are blended together in tanks and packaged. The B-side blending process utilizes internal scrap from a manufacturer’s own operations. Additionally, many facilities utilize technology to minimize the release of gaseous material inputs, such as blowing agents, during material transfer and processing. Waste materials are typically reintegrated into the formulation without additional collection, transport, or processing.

2.2 | PRODUCT INSTALLATION

High-pressure SPF, including open-cell low-density, closed-cell medium density and roofing SPF, is installed by professional applicators by on-site mixing of the A-side and B-side chemicals.



1. Nitrogen/Dry Air System
2. Isocyanate Drum/Tote
3. Isocyanate Transfer Pump
4. Isocyanate Filter
5. Isocyanate Proportioning Pump
6. Isocyanate Primary Heater
7. Isocyanate Output Pressure Gauge
8. Resin Drum/Tote
9. Resin Drum Mixer
10. Resin Transfer Pump
11. Resin Filter
12. Resin Proportioning Pump
13. Resin Primary Heater
14. Resin Output Pressure Gauge
15. Dual Heated Hose
16. Spray Gun
17. Electric Motor
18. Hydraulic Pump
19. Hydraulic Fluid Reservoir
20. Hydraulic Pressure Gauge
21. Hydraulic Directional Valve
22. hydraulic Directional Switch
23. Hydraulic Cylinder
24. Pump Lube System

Figure 3. Schematic of a High-Pressure SPF system

Installation includes insulation of the walls, floors and ceilings of entire buildings, or application as an insulated low-slope roofing system. These chemicals are delivered to the jobsite in unpressurized containers (usually 55-gallon / 208 L drums) and heated to approximately 120-130 °F (49-54 °C) and pressurized to about 1000 psi (6,895 kPa) by specialized equipment. The chemicals are transferred by a heated hose and aerosolized by a spray gun and combined by impingement mixing at the point of application. Personal protective equipment such as goggles, protective suits, and respirator cartridges is required to protect applicators from chemical exposure during installation. Also needed are disposable materials such as masking tape and drop cloths. The schematic in Figure 3 shows the typical equipment components used to produce high-pressure SPF foam, including unpressurized A-side and B-side liquid drums with transfer pumps, which are connected to the proportioner system for heating and pressurizing the chemicals, and then through a heated hose connected to a spray gun for application.

After the foam cures and expands, any excess that may prevent installation of the interior cladding is cut off and discarded. For SPF with physical blowing agents, this study assumes 10% of the installed blowing agent is released to surrounding air during the installation phase. Discarded foam from installation also experiences blowing agent release while in landfill. Disposal of packaging materials is modeled in accordance to the assumptions outlined in Part A of the PCR (UL Environment, 2018). All ancillary installation materials are assumed to be sent to landfill.

2.3 | PACKAGING

High-pressure SPF chemicals are packaged in unpressurized containers of varying types, most commonly in 55-gallon (208 L) steel or plastic drums and in some cases, plastic totes. Since each member company utilizes different package types and sizes, packaging data were aggregated by type (i.e. steel or plastic) and function (i.e. A-side or B-side). Finished packaged products are loaded onto pallets, where additional shipping materials, such as strapping, cardboard, and plastic wrap, are applied. In this study, it is assumed that the empty chemical containers are properly cleaned and taken to a drum recycler.

2.4 | TRANSPORTATION

Final products are distributed via container truck and refrigerated truck, either directly to customers, or first to warehouse, prior to being sent to customers. Table 5 details distribution assumptions for finished SPF products.

2.5 | USE

As this study only looks at the life cycle of spray foam insulation, and not the building, the use phase only contains the emissions of any chemicals off-gassed from the foam. This study assumes 24% of the original chemical blowing agent is off-gassed over a 75-year lifetime (Honeywell International).

2.6 | REFERENCE SERVICE LIFE AND ESTIMATED BUILDING SERVICE LIFE

The reference service life (RSL) for SPF is the life of the building or 75 years. Additional information is provided in Table 7.

2.7 | REUSE, RECYCLING, AND ENERGY RECOVERY

SPF is typically not reused or recycled following its removal from a building. Thus, reuse, recycling, and energy recovery are not applicable for this product.

2.8 | DISPOSAL

When the building is decommissioned, it is assumed that only manual labor is involved to remove the foam. Wastes are assumed to be transported 30 miles (48 km) to the disposal site. The spray foam is assumed to be landfilled at end-of-life, as is typical for construction and demolition waste in the US. This study assumes 16% of the original physical blowing agent is emitted at this stage in the life cycle. It is further assumed the spray foam is inert in the landfill and 50% of the blowing agent remains in the product after disposal (Kjeldsen & Jensen, 2001).

3 Life Cycle Assessment Background Information

3.1 | FUNCTIONAL UNIT

The product function is providing insulation to buildings. Accordingly, the functional unit for the study is 1 m² of installed insulation material with a thickness that gives an average thermal resistance of $R_{SI}=1m^2\cdot K/W$ (In imperial units, $R_{SI}=1$ is equivalent to $R = 5.68\ h\cdot ft^2\cdot °F/Btu$) with a building service life of 75 years (packaging included).

3.2 | SYSTEM BOUNDARY

The study uses a cradle-to-grave system boundary. As such, it includes upstream processing and production of materials and energy resources needed for the production of SPF, transport of materials (all chemical inputs for production and packaging) to SPF formulation sites, formulation of SPF components, transport of the components to the installation site, installation of insulation, removal and transport of insulation to disposal site, and end-of-life-disposal. Building energy savings from the use of insulation are excluded from this analysis.

3.3 | ESTIMATES AND ASSUMPTIONS

SPF is created by mixing equal volumes of two batches of chemicals, commonly referred to as A-side and B-side. “A-side” is the industry term for the isocyanate component of foam; in this case polymeric methylene diphenyl diisocyanate (MDI).

With SPF, "B-side" is a mixture of polyols, fire retardants, blowing agents, catalysts, and other additives that, when mixed with "A-side," creates foam used for insulation. The formulations of these B-side mixtures for each company are proprietary. However, the main ingredients do not vary significantly, so generic formulations are used to represent the B-side products evaluated in this study.

The material and energy inputs and outputs were modeled according to data provided by the representative site, while the electricity grid and natural gas mix were chosen based on the locations of each manufacturer's production facilities. Further granularity of raw material and waste data for additional locations may alter the results of this study.

When possible, energy consumption data on B-side production were collected via sub-metering. However, when not feasible, energy consumption was allocated to the spray polyurethane foam productions by mass.

Lastly, this study assumes 50% of blowing agent consumed in the production of the formulation is eventually emitted, with 10% released during installation, 24% released during lifetime in building, and 16% released during end-of-life. The remaining 50% remains in the product (Honeywell International) (Kjeldsen & Jensen, 2001).

3.4 | CUT-OFF CRITERIA

The cut-off criteria for including or excluding materials, energy and emissions data of the study are as follows:

- **Mass** – If a flow is less than 1% of the cumulative mass of the model it may be excluded, providing its environmental relevance is not a concern.
- **Energy** – If a flow is less than 1% of the cumulative energy of the model it may be excluded, providing its environmental relevance is not a concern.
- **Environmental relevance** – If a flow meets the above criteria for exclusion yet is thought to potentially have a significant environmental impact, it was included. Material flows which leave the system (emissions) and whose environmental impact is greater than 1% of the total of an impact category that has been considered in the assessment must be covered. This judgment was made based on experience and documented as necessary.

Packaging of incoming raw materials (e.g. pallets, totes, super-sacks) are excluded as they represent less than 1% of the product mass and are not environmentally relevant. Capital goods and infrastructure required to produce and install SPF (e.g. batch mixers, spraying equipment) are presumed to produce millions of units over the course of their life, so impact of a single functional unit attributed to these equipment is negligible; therefore, capital goods and infrastructure were excluded from this study. No known flows are deliberately excluded from this EPD.

3.5 | DATA SOURCES

The LCA model was created using the GaBi ts Software system for life cycle engineering, developed by thinkstep AG. The GaBi 2018 LCI database provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

3.6 | DATA QUALITY

A variety of tests and checks were performed by the LCA practitioner throughout the project to ensure high quality of the completed LCA. Checks included an extensive review of project-specific LCA models as well as the background data used.

Temporal coverage

The data are intended to represent spray polyurethane foam production during the 2016 calendar year. As such, each participating SPFA member company provided primary data for 12 consecutive months during the 2016 calendar year. These data were then used to calculate average production values for each company.

Geographical coverage

This background LCA represents SPFA members' products produced in the United States and Canada. Primary data are representative of these countries. Regionally specific datasets 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.

Technological coverage

Data on material composition were developed by a sponsor task group consisting of SPFA and CPI stakeholders to represent the seven products under study. Manufacturing data were collected directly from SPFA members. Waste, emissions, and energy use are calculated from reported annual production during the reference year from SPFA member companies.

3.7 | PERIOD UNDER REVIEW

Primary data collected represent production during the 2016 calendar year. This analysis is intended to represent production in 2016.

3.8 | ALLOCATION

Multi-output allocation generally follows the requirements of ISO 14044, section 4.3.4.2. When allocation becomes necessary during the data collection phase, the allocation rule most suitable for the respective process step was applied.

The cut-off allocation approach is adopted in the case of any post-consumer and post-industrial recycled content, which is assumed to enter the system burden-free. Only environmental impacts from the point of recovery and forward (e.g., inbound transports, grinding, processing, etc.) are considered.

4 Life Cycle Assessment Scenarios

Table 5. Transport to the building site (A4) – HFC and HFO products

NAME	UNIT	ROOFING	CLOSED CELL	OPEN CELL
Fuel type		Diesel	Diesel	Diesel
Fuel economy, outbound transport (large truck, medium truck, refrigerated truck)	l/100km	40.3	40.3	40.3
Fuel economy, jobsite transport (light truck)	l/100km	19.6	19.6	19.6
Outbound distance	km	1683	1683	1683
Jobsite distance	km	0.41	0.41	0.41
Capacity utilization (including empty runs, mass based	%	69	69	69
Weight of products transported (if gross density not reported)	kg	1.39	1.06	0.436

Table 6. Installation into the building (A5) – HFC and HFO products

NAME	UNIT	ROOFING	CLOSED CELL	OPEN CELL
Ancillary materials	kg	0.00576	0.00436	0.0018
Net freshwater consumption specified by water source and fate (amount evaporated, amount disposed to sewer)	m^3	-	-	-
Other resources	kg	-	-	-
Electricity consumption	kWh	0.0734	0.0556	0.023
Diesel for construction equipment	MJ	4.86	3.68	1.52
Product loss per functional unit	kg	0.0453	0.0343	0.0142
Waste materials at the construction site before waste processing, generated by product installation	kg	0.0511	0.0387	0.0160
Output materials resulting from on-site waste processing (specified by route; e.g. for recycling, energy recovery and/or disposal)	kg	-	-	-
Biogenic carbon contained in packaging	kg CO2	0.0138	0.0105	0.00432
Direct emissions to ambient air, soil and water	kg	0.371	0.281	0.115
VOC content	$\mu g/m^3$	-	-	-

Table 7. Reference Service Life

NAME	VALUE	UNIT
RSL	75	Years
Declared product properties (at the gate) and finishes, etc.	1	m^2
	1	R_{SI}

Table 8. End of life (C1-C4)

NAME	UNIT	ROOFING	CLOSED CELL	OPEN CELL
Collected as mixed construction waste	kg	1.23	0.932	0.385
Landfill	kg	1.23	0.932	0.385

Table 9. Reuse, recovery and/or recycling potentials (D), relevant scenario information

NAME	UNIT	ROOFING	CLOSED CELL	OPEN CELL
Net energy benefit from steam recovery from waste treatment declared as exported energy in D	MJ	3.03E-03	2.29E-03	2.29E-03
Net energy benefit from electricity recovery from waste treatment declared as exported energy in D	MJ	3.10 E-03	2.35 E-03	9.72 E-04

5 Life Cycle Assessment Results

As this is a cradle-to-grave declaration, all modules are declared, as seen in Table 10. However, modules B2 to B7, C1, and C3 do not contribute to impact and are therefore declared as zero. In the interest of concision, the following tables in this section do not include the modules.

Table 10. Description of the system boundary modules

	PRODUCT STAGE			CONSTRUC-TION 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
Cradle-to-grave	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

5.1 LIFE CYCLE IMPACT ASSESSMENT RESULTS

North American LCIA results are declared using TRACI 2.1 methodology. Note that the IPCC AR5 GWP (IPCC, 2006) results are also presented as they are more current than the TRACI 2.1 GWP results and represent accurate values for the GWP of the blowing agents. The TRACI 2.1 methodology refers to an earlier version of the IPCC report.

Table 11. Roofing, HFO results

TRACI v2.1	A1-A3	A4	A5	B1	C2	C4	D
GWP 100 [kg CO_2 eq]	4.05E+00	1.62E-01	6.93E-01	-	4.49E-03	5.51E-02	-2.33E-04
GWP 100, IPCC AR5 [kg CO_2 eq]	4.10E+00	1.62E-01	6.76E-01	9.05E-03	4.50E-03	6.17E-02	-2.33E-04
ODP [kg CFC-11 eq]	8.88E-08	4.65E-15	3.63E-13	-	1.30E-16	9.95E-15	-7.44E-16
AP [kg SO_2 eq]	1.32E-02	7.25E-04	4.64E-03	-	2.02E-05	2.50E-04	-1.36E-06
EP [kg N eq]	1.03E-03	6.01E-05	3.44E-04	-	1.68E-06	1.27E-05	-5.19E-08
POCP [kg O_3 eq]	1.92E-01	2.39E-02	1.54E-01	2.81E-03	6.68E-04	6.83E-03	-6.01E-06
ADP_{fossil} [MJ, LHV]	1.03E+01	3.18E-01	1.11E+00	-	8.89E-03	1.08E-01	2.98E-04

Table 12. Closed cell, HFO results

TRACI v2.1	A1-A3	A4	A5	B1	C2	C4	D
GWP 100 [kg CO_2 eq]	3.47E+00	1.22E-01	5.25E-01	-	3.40E-03	4.17E-02	-1.77E-04
GWP 100, IPCC AR5 [kg CO_2 eq]	3.52E+00	1.23E-01	5.12E-01	6.85E-03	3.41E-03	4.67E-02	-1.77E-04
ODP [kg CFC-11 eq]	6.74E-08	3.52E-15	2.75E-13	-	9.84E-17	7.54E-15	-5.63E-16
AP [kg SO_2 eq]	1.07E-02	5.50E-04	3.51E-03	-	1.53E-05	1.89E-04	-1.03E-06
EP [kg N eq]	8.06E-04	4.55E-05	2.61E-04	-	1.27E-06	9.60E-06	-3.93E-08
POCP [kg O_3 eq]	1.53E-01	1.81E-02	1.17E-01	2.13E-03	5.06E-04	5.18E-03	-4.55E-06
ADP_{fossil} [MJ, LHV]	8.49E+00	2.41E-01	8.39E-01	-	6.74E-03	8.21E-02	2.26E-04

Table 13. Open cell results

TRACI v2.1	A1-A3	A4	A5	B1	C2	C4	D
GWP 100 [kg CO_2 eq]	1.42E+00	5.06E-02	1.67E-01	-	1.41E-03	1.72E-02	-7.30E-05
GWP 100, IPCC AR5 [kg CO_2 eq]	1.44E+00	5.08E-02	1.69E-01	-	1.41E-03	1.74E-02	-7.30E-05
ODP [kg CFC-11 eq]	2.77E-08	1.46E-15	1.14E-13	-	4.07E-17	3.12E-15	-2.33E-16
AP [kg SO_2 eq]	4.18E-03	2.27E-04	1.45E-03	-	6.34E-06	7.83E-05	-4.26E-07
EP [kg N eq]	2.85E-04	1.88E-05	1.08E-04	-	5.25E-07	3.97E-06	-1.62E-08
POCP [kg O_3 eq]	6.05E-02	7.50E-03	4.79E-02	-	2.09E-04	1.55E-03	-1.88E-06
ADP_{fossil} [MJ, LHV]	3.46E+00	9.97E-02	3.47E-01	-	2.78E-03	3.39E-02	9.33E-05

5.2 LIFE CYCLE INVENTORY RESULTS

Table 14. Resource Use, Roofing, HFO results

Parameter	A1-A3	A4	A5	B1	C2	C4	D
RPR_E [MJ, LHV]	3.40E+00	5.76E-02	2.85E-01	-	1.61E-03	6.12E-02	-1.02E-03
RPR_M [MJ, LHV]	1.38E-01	-	2.78E-03	-	-	-	-
$NRPR_E$ [MJ, LHV]	8.77E+01	2.38E+00	8.77E+00	-	6.65E-02	8.67E-01	-3.24E-03
$NRPR_M$ [MJ, LHV]	3.56E+01	-	9.73E-01	-	-	-	-
SM [kg]	-	-	-	-	-	-	-
RSF [MJ, LHV]	-	-	-	-	-	-	-
NRSF [MJ, LHV]	-	-	-	-	-	-	-
RE [MJ, LHV]	-	-	-	-	-	-	-
FW [m^3]	1.75E-02	2.84E-04	1.50E-03	-	7.92E-06	1.05E-04	-2.86E-06

Table 15. Resource Use, Closed cell, HFO results

Parameter	A1-A3	A4	A5	B1	C2	C4	D
RPR_E [MJ, LHV]	2.90E+00	4.37E-02	2.16E-01	-	1.22E-03	4.63E-02	-7.73E-04
RPR_M [MJ, LHV]	1.05E-01	-	2.11E-03	-	-	-	-
$NRPR_E$ [MJ, LHV]	7.23E+01	1.80E+00	6.64E+00	-	5.04E-02	6.56E-01	-2.46E-03
$NRPR_M$ [MJ, LHV]	2.47E+01	-	7.37E-01	-	-	-	-
SM [kg]	-	-	-	-	-	-	-
RSF [MJ, LHV]	-	-	-	-	-	-	-
NRSF [MJ, LHV]	-	-	-	-	-	-	-
RE [MJ, LHV]	-	-	-	-	-	-	-
FW [m^3]	1.40E-02	2.15E-04	1.14E-03	-	6.00E-06	7.95E-05	-2.16E-06

Table 16. Resource Use, Open cell results

Parameter	A1-A3	A4	A5	B1	C2	C4	D
RPR_E [MJ, LHV]	9.42E-01	1.80E-02	8.93E-02	-	5.04E-04	1.91E-02	-3.20E-04
RPR_M [MJ, LHV]	4.33E-02	-	8.72E-04	-	-	-	-
$NRPR_E$ [MJ, LHV]	2.92E+01	7.46E-01	2.74E+00	-	2.08E-02	2.71E-01	-1.01E-03
$NRPR_M$ [MJ, LHV]	9.14E+00	-	3.05E-01	-	-	-	-
SM [kg]	-	-	-	-	-	-	-
RSF [MJ, LHV]	-	-	-	-	-	-	-
NRSF [MJ, LHV]	-	-	-	-	-	-	-
RE [MJ, LHV]	-	-	-	-	-	-	-
FW [m^3]	4.82E-03	8.88E-05	4.70E-04	-	2.48E-06	3.28E-05	-8.94E-07

Table 17. Output Flows and Waste Categories, Roofing, HFO

PARAMETER	A1-A3	A4	A5	B1	C2	C4	D
HWD [kg]	2.07E-06	1.86E-08	4.90E-08	-	5.20E-10	2.98E-09	-2.06E-12
NHWD [kg]	7.12E-02	8.60E-05	9.80E-02	-	2.40E-06	1.23E+00	-1.74E-06
HLRW [kg]	2.48E-06	5.08E-09	1.18E-07	-	1.42E-10	1.12E-08	-8.26E-10
ILLRW [kg]	3.22E-05	1.37E-07	3.24E-06	-	3.82E-09	2.67E-07	-2.28E-08
CRU [kg]	-	-	-	-	-	-	-
MR [kg]	-	-	6.05E-02	-	-	-	-
MER [kg]	-	-	-	-	-	-	-
EE, Steam [MJ, LHV]	3.77E-04	-	2.65E-03	-	-	-	-
EE, Electricity [MJ, LHV]	8.01E-04	-	2.30 E-03	-	-	-	-

Table 18. Output Flows and Waste Categories, Closed cell, HFO results

PARAMETER	A1-A3	A4	A5	B1	C2	C4	D
HWD [kg]	1.89E-06	1.41E-08	3.71E-08	-	3.94E-10	2.26E-09	-1.56E-12
NHWD [kg]	5.51E-02	6.52E-05	7.42E-02	-	1.82E-06	9.34E-01	-1.32E-06
HLRW [kg]	2.10E-06	3.85E-09	8.94E-08	-	1.08E-10	8.51E-09	-6.26E-10
ILLRW [kg]	3.01E-05	1.04E-07	2.45E-06	-	2.89E-09	2.03E-07	-1.73E-08
CRU [kg]	-	-	-	-	-	-	-
MR [kg]	-	-	4.58E-02	-	-	-	-
MER [kg]	-	-	-	-	-	-	-
EE, Steam [MJ, LHV]	2.86E-04	-	2.01E-03	-	-	-	-
EE, Electricity [MJ, LHV]	6.07E-04	-	1.74E-03	-	-	-	-

Table 19. Output Flows and Waste Categories, Open cell results

PARAMETER	A1-A3	A4	A5	B1	C2	C4	D
HWD [kg]	1.09E-07	5.83E-09	1.53E-08	-	1.63E-10	9.34E-10	-6.46E-13
NHWD [kg]	2.46E-02	2.69E-05	3.07E-02	-	7.53E-07	3.86E-01	-5.45E-07
HLRW [kg]	8.15E-07	1.59E-09	3.69E-08	-	4.45E-11	3.52E-09	-2.59E-10
ILLRW [kg]	1.13E-05	4.28E-08	1.01E-06	-	1.20E-09	8.37E-08	-7.14E-09
CRU [kg]	-	-	-	-	-	-	-
MR [kg]	-	-	1.89E-02	-	-	-	-
MER [kg]	-	-	-	-	-	-	-
EE, Steam [MJ, LHV]	1.18E-04	-	8.30E-04	-	-	-	-
EE, Electricity [MJ, LHV]	2.51E-04	-	7.21E-04	-	-	-	-

6 LCA Interpretation

This study assumes 50% of blowing agent consumed in the production of the formulation is eventually emitted, with 10% released during installation, 24% released during lifetime in building, and 16% released during end-of-life (Honeywell International) (Kjeldsen & Jensen, 2001). For HFC containing products, installation (A5), use (B1), and disposal (C4) are the greatest contributors to the GWP category due the emissions of HFCs over the course of its lifecycle. HFO formulations and open cell do not have pronounced GWP impacts across the life cycle due to lower blowing agent GWP characterization factors.

In nearly all other impact categories, SPF environmental performance is driven primarily by raw materials (A1), in particular polyols and TCPP due to their high mass contribution to the product. Installation tends to be the second highest driver of impact due to the use of on-site diesel generator, as well as waste foam disposal.

Though some raw materials are transported thousands of miles, the inbound transportation module (A2) has a modest contribution to overall impact. Other transportation modules representing transport to site (A4) and transport to end-of-life (C2), have negligible contribution to life cycle results.

7 Additional Environmental Information

7.1 ENVIRONMENT AND HEALTH DURING MANUFACTURING

Manufacturing of SPF formulations and upstream chemicals are performed in an industrial manufacturing facility. Like many manufacturing processes, hazardous chemicals and manufacturing procedures may be employed. These manufacturers follow all local, state and federal regulations regarding safe use and disposal of all chemicals (US EPA), as well as safety requirements required of the generally manufacturing operation of equipment and processes (US and State OSHA) and safe transport of all materials (US DOT) Environment and Health During Installation

Installation of SPF involves potential exposure to certain hazardous chemicals that requires risk mitigation through the use of personal protective equipment and on-site actions including ventilation and restricted access. Of greatest concern is the potential exposure to airborne and liquid isocyanates during and immediately after installation of SPF. Isocyanates are known chemical sensitizers and exposure can occur through contact with the skin, eyes and respiratory system. Ventilation of the work zone, coupled with use of proper personal protective equipment is required during and immediately after installation SPF. For more information on health and safety during and immediately after SPF installation, please visit www.spraypolyurethane.org

7.2 EXTRAORDINARY EFFECTS

Fire

Spray polyurethane foam, like all foam plastics and many construction materials – including wood - is a combustible material and will emit toxic gases including carbon monoxide during a fire. When used in buildings and other construction applications, foam plastics employ flame retardants to control ignition the spread of fire and development of smoke. In addition, foam plastics may need to be protected with fire-resistant coverings or coatings when used in certain construction applications, as dictated by the building codes. All foam plastics materials and assemblies should meet the fire test requirements of the applicable building codes.

Water

Closed-cell and roofing SPF products meet the FEMA Class 5 requirements[3] for flood-damage resistant insulation materials for floors and walls.

[3] “Flood Damage-Resistant Materials Requirements”, FEMA Technical Bulletin 2, 2008, Table 2.

Mechanical Destruction

Should the assembly the SPF is installed in, i.e. the wall or roof, have to be replaced then the SPF will have to be replaced as well.

7.3 ENVIRONMENTAL ACTIVITIES AND CERTIFICATIONS

Several SPF manufacturers have certified or tested their insulation products to various VOC standards to measure emissions of volatile or semi-volatile compounds. These standards include:

- UL Environment GREENGUARD® Certification – The GREENGUARD® Certification Program specifies strict certification criteria for VOC's and indoor air quality. This voluntary program helps consumers identify products that have low chemical emissions for improved indoor air quality.
- California Department of Health Services – Also known as Section 01350, this small-chamber emissions test standard is detailed under: Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers (CA/DHS/EHLB/Standard Method v1.1-2010).
- Canadian ULC – Required for SPF insulation products, this standard provides a similar VOC emissions test protocol specifically for SPF: CAN/ULC S774-09 Standard Laboratory Guide for the Determination of Volatile Organic Compound Emissions from Polyurethane Foam
- Currently, an ASTM workgroup is developing a small-chamber emissions test protocol for chemical compounds specific to SPF that include MDI, blowing agents, flame retardants and catalysts.

7.4 NATURAL OIL POLYOLS

Natural Oil Polyols, or NOPs, are being used in some spray foam formulations, as some manufacturers are using renewable materials in their formulation to help differentiate their products from conventional petroleum-based materials. NOPs may include vegetable oils such as soy, castor, glycerin and rapeseed. This LCA was based on conventional petroleum-based polyols, as these are the most widely used in the industry and more representative of most current spray foam formulations.

7.5 LOW-GWP BLOWING AGENTS FOR SPF

This EPD is based on an LCA of SPF products that use HFOs as blowing agents. Because of the low global warming potential factor of HFOs (~1.0 g CO_2-eq./kg) the emissions of these blowing agents account for a small percentage of the global warming potential life cycle results for HFO containing foams.

A concurrent EPD study was also conducted for SPF products with high GWP blowing agents – HFC-134a and HFC-245fa (SPFA, 2018). While the formulations used in this study allow for the assumption that HFC and HFO may be replaced with one another, actual production practices may not always allow for interchangeability. However, despite being released at the same rate over the course of the life of the product as HFOs, HFCs have a substantially higher contribution to GWP due to their GWP characterization factor of HFC-134a and HFC-245fa (1,300 and 858 kg CO_2-eq./kg, respectively, over a 100 year time horizon (IPCC, 2006))[4].

[4] Note that the TRACI 2.1 GWP methodology uses an earlier version of the IPCC report where the characterization factors of HFC-134a and HFC-245fa are 1,430 and 1,030 kg CO_2-eq./kg, respectively.

Appendix: List of Applicable Manufacturers and Products

	Open-Cell	Closed-Cell (HFO)	Roofing (HFO)
Accella	Bayseal OC Bayseal OCHY Quadfoam 500 Quadfoam 500OC Quadfoam Natureseal Foamsulate 50 Foamsulate 50HY Foamsulate N-IB Sealtite OC+	SealTite CC+	SealTite Roof 60+ SealTite Roof 40+
BASF	Enertite (all lines)	Walltite HFO Walltite CMxx lines	Skytite C3 and C4 lines
DAP			
Demilec	Sealection® 500 Agribalance® Demilec APX® 1.2 Sealection® NM Demilec APX® 2.0	Heatlok®HFO High Lift Heatlok® HFO Pro	
Dow			
General Coatings	Ultra-Thane 050 UPC 500 UPC 500 HIGH YIELD UPC 500 MAX	Ultra-Thane 200 UPC 2.0 HFO	Ultra-Thane 250 Ultra-Thane 270 Ultra-Thane 300 UPC 2.5 HFO UPC 2.7 HFO UPC 3.0 HFO
Gaco-Western	GacoProFill GacoEZSpray GacoFireStop2 Gaco 052N GacoInsulBarrier (Canada)	GacoOnePass Low GWP	

ICP Adhesives and Sealants			
Icynene-Lapolla	Classic™ Classic Ultra™ Classic Ultra Select™ Classic Plus™ FOAM-LOK® FL400 FOAM-LOK® FL450 FOAM-LOK® FL500 FOAM-LOK® FL750	ProSeal HFO™ FOAM-LOK® FL 2000-4G	LPA 2500-4G LPA 2800-4G LPA 3000-4G
Johns-Manville	JM Corbond ocSPF JM Corbond OCX SPF	JM Corbond IV	
NCFI Polyurethanes	Sealite™	InsulStar® InsulBloc®	EnduraTech™
SES	Sucraseal™ 0.5 EasySeal.5	Nexseal™ 2.0 Nexseal™ 2.0 LE	Nexseal™ 2.3/3.3 Series

References

EN 15804: Sustainability of construction works, Environmental product declarations, Core rules for the product category of construction products. (2013). European Committee for Standardization.

EPA. (2012). *Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) - User's Manual.* Washington, D.C.: US EPA.

Honeywell International. (n.d.). *Predictive Model for Polyurethane Blowing Agent Emissions into a House.* Buffalo.

Institute of Environmental Sciences (CML), Leiden University. (2012, October). CML-IA database v4.1. Netherlands.

IPCC. (2006). *Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste; IPCC Waste Model.* Retrieved from http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

ISO. (2006). *ISO 14025: Environmental labels and declarations - Type III environmental declarations - Principles and procedures.* Geneva: International Organization for Standardization.

ISO. (2006). *ISO 14040: Environmental management - Life cycle assessment - Requirements and guidelines.* Geneva: International Organization for Standardization.

ISO. (2006). *ISO 14044: Environmental management - Life cycle assessment - Principles and framework.* Geneva: International Organization for Standardization.

ISO. (2007). *ISO 21930: Sustainability in building construction - Environmental declaration of building products.* Geneva: International Organization for Standardization.

ISO. (2017). *ISO 21930: Sustainability in buildings and civil engineering works -- Core rules for environmental product declarations of construction products and services.* Geneva: International Organization for Standardization.

Kjeldsen, P., & Jensen, M. (2001). Release of CFC-11 from Disposal of Polyurethane Foam Waste. *ENVIRONMENTAL SCIENCE & TECHNOLOGY*, 3055-3063.

SCS Global Services. (2015). North American PCR for Designated Steel Construction Products.

SPFA. (2018). *Environmental Product Declaration: Spray Polyurethane Foam Insulation.* ASTM.

thinkstep. (2016). GaBi LCA Database Documentation. Retrieved from thinkstep AG: http://www.gabi-software.com/international/databases/gabi-databases/.

UL Environment. (2018). *Product Category Rules (PCR) Guidance for Building-Related Products and Services Part B: Building Envelope Thermal Insulation EPD Requirements, UL 10010–1 (v2.0).*

UL Environment. (2018). *Product Category Rules for Building-Related Products and Services - Part A: Life Cycle Assessment Calculation Rules and Report Requirements, UL 10010 (v3.1).*

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