Environmental Product Declaration

Built-Up Asphalt Roofing Membrane

INSTALLATION: FASTENED BASE, 2 PLY FELTS AND CAP IN HOT ASPHALT

Low-slope roofing membrane of a built-up roof (BUR).

The Asphalt Roofing Manufacturers Association (ARMA) is a trade association representing North America's asphalt roofing manufacturing companies and their raw material suppliers. The association includes the majority of North American manufacturers of asphalt shingles and asphalt low slope roof membrane systems. Information that ARMA gathers on modern asphalt roofing materials and practices is provided to building and code officials, as well as regulatory agencies and allied trade groups. Committed to advances in the asphalt roofing industry, ARMA is proud of the role it plays in promoting asphalt roofing to those in the building industry and to the public.

ARMA's vision and mission is to be an association committed to the long-term sustainability of the asphalt roofing industry and to advocate and advance the interests of the asphalt roofing industry by leveraging the collective expertise of its members

CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION UL.COM/EPD

1. Content of the EPD

EPD PROGRAM AND PROGRAM OPERATOR NAME, ADDRESS, LOGO, AND WEBSITE	UL ENVIRONMENT 333 PFINGSTEN RD, NORTHBROOK, IL 60062 WWW.UL.COM WWW.SPOT.UL.COM
GENERAL PROGRAM INSTRUCTIONS AND VERSION NUMBER	Program Operator Rules v 2.7 2022
MANUFACTURER NAME AND ADDRESS	Asphalt Roofing Manufacturers Association, 2331 Rock Spring Road, Forest Hill, MD 21050
DECLARATION NUMBER	4789862118.110.2
DECLARED PRODUCT & FUNCTIONAL UNIT OR DECLARED UNIT	1 m^2 Built-Up Asphalt Roofing Membrane (Installation: Hybrid)
REFERENCE PCR AND VERSION NUMBER	Part A: Life Cycle Assessment Calculation Rules and Report Requirements (UL Environment, 2022); Part B: Asphalt Shingles, Built-up Asphalt Membrane Roofing and Modified Bituminous Membrane Roofing EPD Requirements (ULE, 2021)
DESCRIPTION OF PRODUCT APPLICATION/USE	Built-Up Asphalt Roofing Membrane (Installation: Hybrid)
MARKETS OF APPLICABILITY	North America
DATE OF ISSUE	July 1, 2023 (Data Update February 2024)
PERIOD OF VALIDITY	5 Years
EPD TYPE	Industry-average
RANGE OF DATASET VARIABILITY	2014 - 2021
EPD SCOPE	Cradle to gate with options (construction, and end-of-life (EoL) stages)
YEAR(S) OF REPORTED PRIMARY DATA	2019
LCA SOFTWARE & VERSION NUMBER	LCA for Experts v10.7 (formerly GaBi) (Sphera, 2023)
LCI DATABASE(S) & VERSION NUMBER	Managed LCA Content (formerly GaBi databases) CUP 2022.2
LCIA METHODOLOGY & VERSION NUMBER	IPCC AR5 , CML-IA v4.8, and TRACI 2.1

The PCR review was conducted by:	UL Environment PCR Review Panel epd@ul.com
This declaration was independently verified in accordance with ISO 14025: 2006. ☐ INTERNAL ☒ EXTERNAL	Cooper McCollum, UL Environment *Cooper McCollum*
This life cycle assessment was conducted in accordance with ISO 14044 and the reference PCR by:	Sphera
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	Thomas P. Gloria, Industrial Ecology Consultants *Thomas Gloria*

LIMITATIONS

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

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

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

2. General Information

2.1. Description of Company/Organization

The following ARMA members provided data for the product covered within this document:

CertainTeed
www.certainteed.com

Holcim Building Envelope
www.holcimelevate.com

Johns Maniville
www.jm.com

Malarkey Roofing
www.malarkeyroofing.com

2.2. Product Description

The low-slope roofing membrane included in this study consists of built-up roof (BUR) cap and base sheets and two ply felts.

Table 1 shows the specifications for these products along with a brief description. Figure 1 shows few examples of the different datasets included in the production process.

Table 1: Specification and Description of the cap sheet, base sheet and ply felt

COMPONENT	SPECIFICATION	DESCRIPTION
BUR Cap Sheet	ASTM D3909	- Mineral-surfaced BUR cap sheets consist of asphalt-impregnated and coated glass felt roll roofing surfaced on the weather side with colored mineral granules
BUR Ply Felt	ASTM D2178; CSA A123.17	- Ply felts consist of glass felts impregnated with oxidized asphalt - A fine mineral matter parting agent is typically applied to facilitate use during installation
BUR Base Sheet	ASTM D4601, CSA A123.16	- Fiberglass mat coated with oxidized asphalt A fine mineral matter may be applied as a surfacing or parting agent to both sides of the base sheets

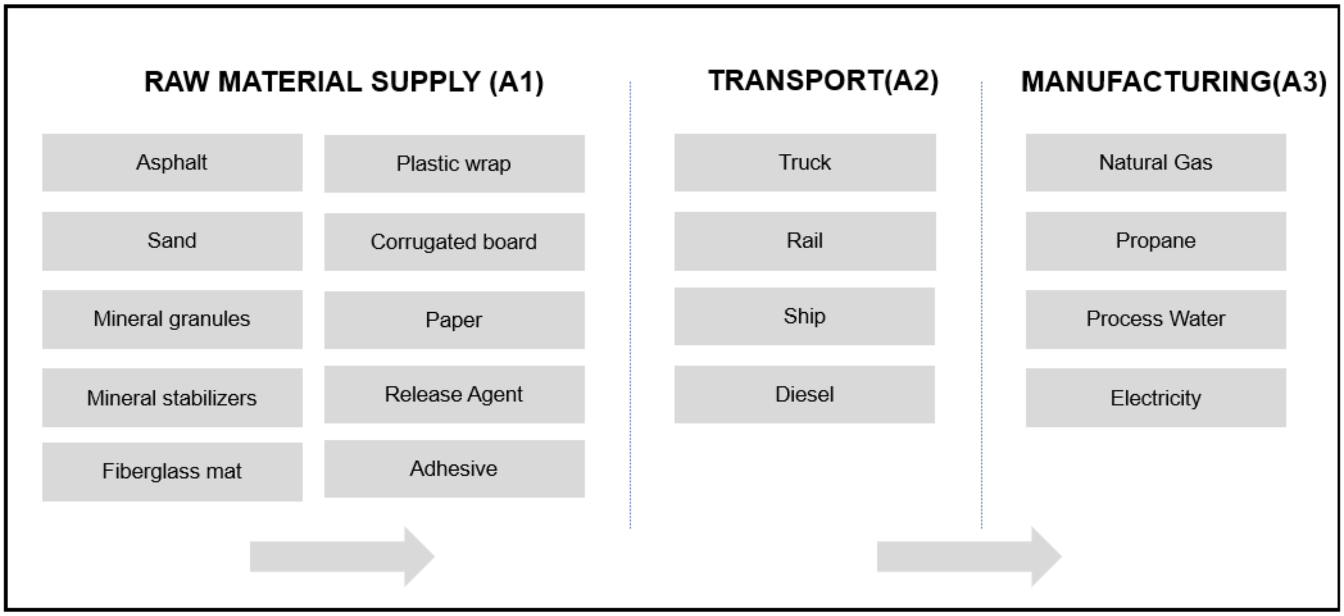

Figure 1: Production process overview

2.3. Product Average

This EPD represents an industry-average product. Facility-level production data was collected from participating members of ARMA for their respective facilities that manufacture this product. A weighted average was then calculated based on each facility's production amounts in mass.

2.4. Application

Low-slope roofing systems are installed on roofs with slopes less than 2:12. Low-slope roofing systems are primarily used to protect buildings and structures from the weather.

One significant benefit of BUR systems is the protection provided by the multiple water-resistant layers. These systems are durable and can stand up to weather conditions, temperature extremes, impacts, and foot traffic. BUR roofing systems can be installed in a variety of ways to meet many building design requirements.

2.5. Material Composition

Table 2 shows the percent (%) composition (by weight) of the components of the built-up asphalt roofing system. Percentage values provided in the parenthesis for components represent the weight % of these components in the overall installed roofing system, which also includes the weight of installation materials. Therefore, the sum of the % values in parenthesis might not add up to 100% due to the weight of installation materials in the overall installed system.

Table 2: Average material inputs for BUR cap, base and ply felt manufacturing.

MATERIAL INPUTS	WEIGHT PERCENTAGE IN INDIVIDUAL COMPONENT
BUR Mineral Cap sheet (36% of representative roofing system)	
Mineral granules	42%
Limestone	24%
Asphalt	22%
Sand	9%
Fiberglass mat	3%
BUR Mineral Base sheet (12% of representative roofing system)	
Mineral granules	<1%
Limestone	14%
Asphalt	41%
Release agent (soaps, sodium cocoate)	<1%
Fiberglass mat	13%
Sand	32%
BUR Ply Felt (17% of representative roofing system)	
Asphalt	51%
Limestone	9%
Fiberglass mat	16%
Sand	24%
Release agent (soaps, sodium cocoate)	<1%

2.6. Technical Requirements

Table 3: Product ASTM International and CSA Group Specifications

PRODUCT CATEGORY	PRODUCT	DESCRIPTION/SPECIFICATION
BUR Hybrid Cap Sheet, Base sheet, 2xPly Felt	Cap Sheet	ASTM D3909
	Ply Felt	ASTM D2178; CSA A123.17
	Base Sheet	ASTM D4601; CSA A123.16

2.7. Properties of Declared Product as Delivered

The BUR asphalt hybrid roofing membrane products comply with one or more of ASTM D3909; ASTM D2178; CSA A123.17; ASTM D4601; CSA A123.16.

3. Methodological Framework

3.1. Declared Unit

The declared unit of this study is 1 m^2 (10.8 ft^2) of the installed roofing membrane. The associated reference flow (the quantity of material required to fulfill the declared unit) is 11.36 kg/m^2.

3.2. System Boundary

The life cycle study encompasses the cradle-to-gate production, construction, and end-of-life (EoL) stages of the built-up hybrid roofing membrane, including raw material extraction and processing, product manufacturing and installation, plus deconstruction, waste processing and material disposal at EoL. Transportation between stages is accounted for, including raw material transport to the manufacturing facility, finished product transport to the construction site, and transport of the roof system at EoL to the landfill. Asphalt roofing systems do not have any operational energy or resources consumption, and it can be assumed that the impacts of maintenance of these roofing systems will also be negligible. Therefore, use, maintenance, repair, or replacement of the roof system over a building's service life have been excluded from the system boundary. Moreover, a reference service lifetime (RSL) has not been provided as it is not mandatory according to the PCR. In addition, production, manufacture and construction of manufacturing equipment and infrastructure; repair and maintenance of the production system; energy and water use related to company management and sales; delivery vehicles and laboratory equipment; as well as maintenance and operation of support equipment are all outside of the scope of the study.

Table 4: Description of the system boundary modules

PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY
A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
Raw material supply	Transport	Manufacturing	Transport from gate to site	Assembly/ Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Building Operational Energy Use During Product Use	Building Operational Water Use During Product Use	Deconstruction	Transport	Waste processing	Disposal	Reuse, Recovery, Recycling Potential
X	X	X	X	X	MND	MND	MND	MND	MND	MND	MND	X	X	X	X	MND

MND = module not declared

C1 is zero because deconstruction is done manually, and the energy consumed during this process is insignificant. C3 is zero because there is no waste processing required before sending the product for disposal in landfill.

3.3. Allocation

As several products are often manufactured at the same plant, participating companies used mass allocation to report data since the environmental burden in the industrial process (energy consumption, emissions, etc.) is primarily governed by the mass throughput of each sub-process.

All packaging waste generated during installation, as well as 40% of the wooden pallets used for shipping of products, are assumed to be sent to landfill. Cut-off approach is applied, hence, no credit is assigned in this study.

The impacts due to the use of any recycled materials during manufacturing come only from further processing required during the recycling process. For the primary data, where in-house recycling is used to create other products, co-product allocation by mass is used and any additional processing steps required for use of the recovered materials are accounted for. It is conservatively assumed that all roofing materials disposed at EoL are sent to landfill. This will vary from job site to job site as some roofers may recycle metal components.

3.4. Cut-off Criteria

No cut-off criteria are defined for this study. The system boundary was defined based on relevance to the goal of the study. For the processes within the system boundary, all available energy and material flow data were included in the model. In cases where no matching life cycle inventories were available to represent a flow, proxy data was applied based on conservative assumptions regarding environmental impacts.

3.5. Data Sources

Technological: At least 75% of the production market is estimated to be represented within this study.

Geographical: The geographic coverage represented by this study is the United States and Canada, though some manufacturers source their raw materials from outside this region. Whenever U.S. background data were not readily available, European data or global data were used as proxies, depending on appropriateness and availability. Results are presented as production weighted averages for the U.S. and Canada.

Background Data: The LCA model was created using LCA for Experts (formerly GaBi Professional) Software system for life cycle engineering, developed by Sphera. The Managed LCA Content (formerly GaBi databases) 2022 provides the LCI data for several of the raw and process materials obtained from the background system. The temporal range for these background data are from 2014-2021. Secondary data, or any assumptions around the secondary data, used to fill data gaps have been adapted from the pre-existing model that was verified as a part of the original EPD verification process in 2016.

3.6. Data Quality

As the relevant foreground data is primary data or modeled based on primary information sources of the owner of the technology, no better precision is reachable within this product. Seasonal variations and variations across different manufacturers were balanced out by using yearly averages and weighted averages. All primary data were collected with the same level of detail, while all background data were sourced from the the Managed LCA Content (formerly GaBi databases) (Sphera, 2023). Allocation and other methodological choices were made consistently throughout the model.

3.7. Period under Review

Primary data, collected from the participating ARMA member companies, is representative of the year 2019.

3.8. Estimates and Assumptions

The analysis uses the following assumptions:

- Mineral granules can be made in a variety of colors, which affects the composition of the required mineral granule coating. White mineral granules were selected as a representative product for this study because the pigment used for white products, titanium dioxide, generally has a higher impact than other pigments; therefore, using white is a conservative assumption.
- Where a manufacturer was unable to calculate an average distance for the distribution of its final product from its facility, it provided a best estimate.
- Due to lack of data availability some proxy background data were used, specifically in the context of the geographical scope of the study.

4. Technical Information and Scenarios

4.1. Manufacturing

BUR Mineral-surfaced Cap Sheet

Manufacture of mineral-surfaced cap sheets involves impregnating and coating a fiberglass mat with a filled asphalt coating. The filled coating mixture is produced in a separate process that involves mixing oxidized asphalt and limestone (or other suitable mineral stabilizer) in appropriate proportions. Colored mineral granules are added as surfacing. Fine mineral matter may be used as a parting agent. The product is cooled, wound into rolls, and packaged for shipment.

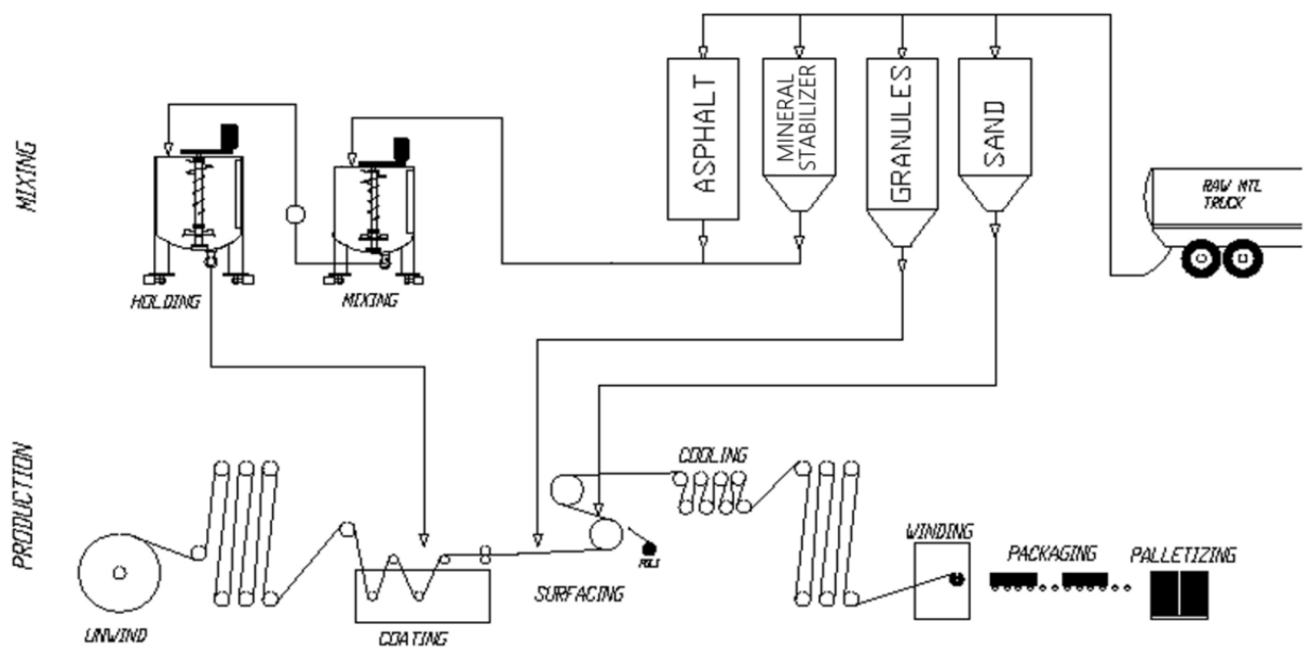

Figure 2: Mineral-surfaced cap sheet process diagram

BUR Ply felt

Manufacture of ply felts involves impregnating a fiberglass mat with oxidized asphalt. A fine mineral matter parting agent is typically applied to facilitate installation. The product is cooled, wound into rolls, and packaged for shipment.

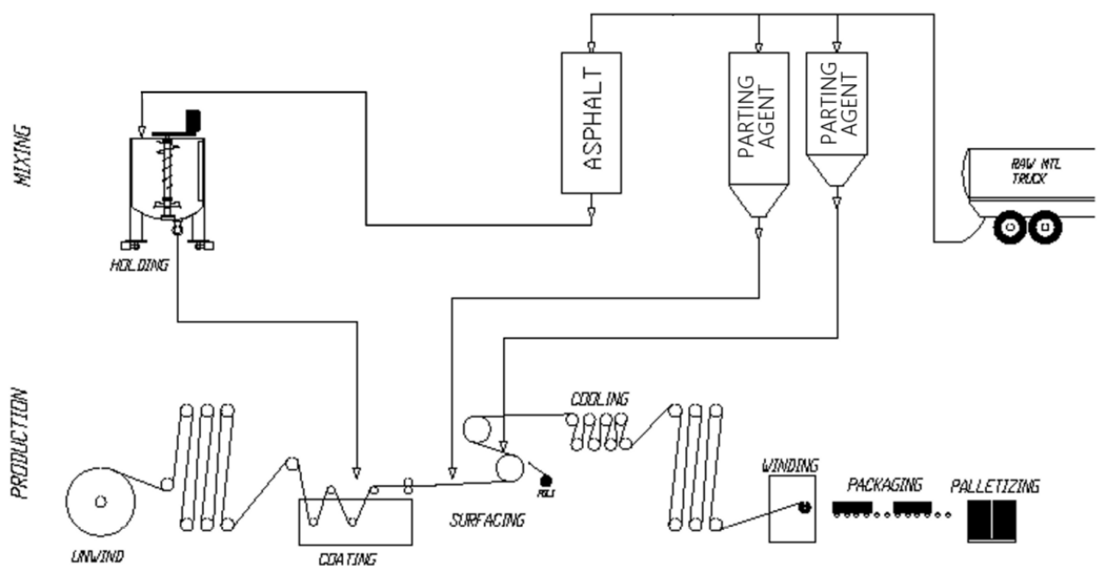

Figure 3: Ply felt process diagram

BUR Base Sheet

Manufacture of BUR base sheets involves impregnating and coating a fiberglass mat with an oxidized asphalt mixed with a mineral stabilizer. A fine mineral matter parting agent is typically applied to both sides to facilitate installation. The product is cooled, wound into rolls, and packaged for shipment.

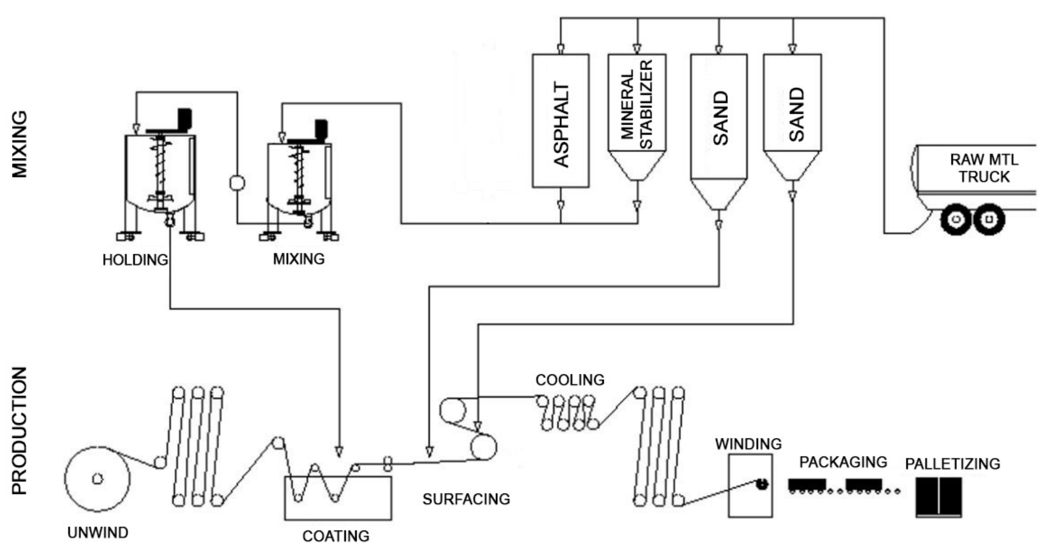

Figure 4: Base sheet process diagram

4.2. Packaging

Adhesive, pallets, plastic film, corrugated core packaging material are used. It's assumed that pallets are reused 20 times. Packaging materials are assumed to be disposed based on region specific disposal rates mentioned in (EPA, 2020)

Table 5: Packaging disposal rate assumptions from the EPA, 2020

PRODUCT	RECYCLED	INCINERATED	LANDFILLED
Paper packaging	81%	4%	15%
Plastic packaging	14%	17%	69%
Wood packaging	27%	14%	59%

4.3. Transportation

Production-weighted averages for the transportation distances and modes of transport associated with each participating company are included for the transport of the raw materials to production facilities and the transport of the finished products to distribution centers. As defined by the Part B PCR, the transport of finished products from the point of manufacture to the construction site is assumed to be 497 miles (800km) and the waste transport distance from the construction site to landfill is 100 miles (161km) (ULE, 2021).

Table 6: Transport to the building site (A4)

NAME	VALUE	UNIT
Fuel type	Diesel	
Liters of fuel	2.21	l/100km
Vehicle type	Truck	
Transport distance	497	miles
Capacity utilization (including empty runs, mass-based)	75	%
Gross density of products transported	11.36	kg/m^2
Weight of products transported (if gross density not reported)	-	kg
Volume of products transported (if gross density not reported)	-	m^3
Capacity utilization volume factor (factor: =1 or <1 or ≥ 1 for compressed or nested packaging products)	1	-

* The unit of gross density is changed to kg/m^2 from kg/m^3 based on the functional unit due to calculation constraints.

4.4. Product Installation

For this EPD, a BUR membrane consists of one base sheet, two ply felts and a mineral-surfaced cap sheet. Hybrid BUR installation requires the base sheet to be mechanically fastened to the substrate and the two ply felts and cap sheet to be attached using hot asphalt, with each sheet overlapping the neighboring sheet's selvedge. Asphalt kegs are heated in a propane-fueled kettle to the required temperature and viscosity for their application, and the ply felts unrolled directly into the asphalt and broomed into place. The same process is used to install the mineral-surfaced cap sheet on top of the two-ply layer of felts. Mineral granules are applied to the asphalt that has migrated out of the cap sheet seams to protect it from UV and for aesthetic reasons.

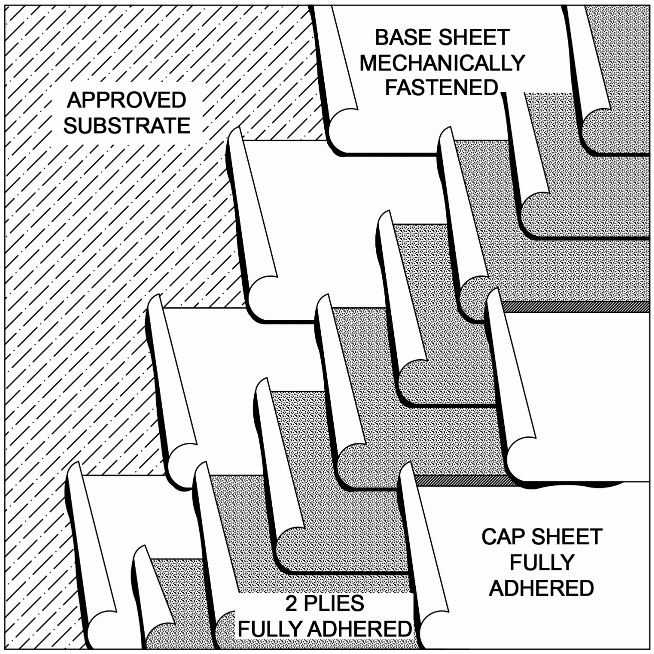

Figure 5: Built-up roofing system installation detail

Table 7: Installation into the building (A5)

NAME	VALUE	UNIT
Ancillary materials	3.89	kg
Net freshwater consumption specified by water source and fate (amount evaporated, amount disposed to sewer)	-	m^3
Other resources	-	kg
Electricity consumption	-	kWh
Other energy carriers	3.75	MJ
Product loss per functional unit	0.37	kg
Waste materials at the construction site before waste processing, generated by product installation	0.76	kg
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	0.17	kg CO_2
Direct emissions to ambient air, soil and water	-	kg
VOC emissions	0.015	kg/m^2

* The unit of VOC emissions is changed to kg/m^2 from µg/m^3 based on the functional unit due to calculation constraints.

Table 8 below presents the installation details for the membrane. The effective coverage includes the required overlap of sheets while the scrap rate accounts for material wasted during installation. VOC emissions from the asphalt kettle are calculated using EPA's Area Source Category Method (EPA, 2000).

Table 8: Roofing system installation inputs and outputs (A5), per 1 m^2

MATERIAL	WEIGHT OF MATERIAL [KG/M^2 MATERIAL]	EFFECTIVE COVERAGE [M^2 OF MATERIAL / M^2 OF CONSTRUCTED ROOF]	SCRAP %	REQUIRED QUANTITY OF MATERIAL [KG/M^2 CONSTRUCTED ROOF]	SOURCE
Mineral Base Sheet	1.25	1.08	5%	1.42	(Sphera, 2016)
Mineral Cap Sheet	3.90	1.06	5%	4.34	(Sphera, 2016)
Ply Felt	0.46	2.16	5%	2.09	(Sphera, 2016)
Flashing	0.10	N/A	10%	0.11	(Sphera, 2016)
Nails	0.06	N/A	-	0.06	(Sphera, 2016)
Asphalt (Type IV)	3.67	-	5%	3.85	(Sphera, 2016)
Mineral granules (at seams)	0.06	-	-	0.06	(Sphera, 2016)
Propane heated kettle (MJ/m^2)	3.75	-	-	3.75	PCR
Diesel fueled asphalt pump (MJ/m^2)	0.0008	-	-	0.0008	PCR
Outputs					
Installed System				11.36	
Waste				0.57	
VOCs (kg/m^2)				0.015	(Sphera, 2016)

4.5. Disposal

At the end-of-life, the low-slope membrane is removed by manual labor, often with roofing shovels. The debris is collected and transported off-site via truck. The waste is brought to a landfill.

Table 9: End of life (C1-C4)

NAME		VALUE	UNIT
Assumptions for scenario development (description of deconstruction, collection, recovery, disposal method and transportation)		Landfill	
Collection process (specified by type)	Collected separately		kg
	Collected with mixed construction waste	11.36	kg
Recovery (specified by type)	Reuse		kg
	Recycling		kg
	Landfill	11.36	kg
	Incineration		kg
	Incineration with energy		kg

NAME		VALUE	UNIT
	recovery		
	Energy conversion efficiency rate		
Disposal (specified by type)	Product or material for final deposition	11.36	kg
Removals of biogenic carbon (excluding packaging)		N/A	kg CO_2

5. Environmental Indicators Derived from LCA

Environmental Product Declarations (EPDs) created under a different Product Category Rule (PCR) are not comparable. Additionally, EPDs based on a declared unit shall not be used for comparisons between products, regardless of the EPDs using the same PCR.

Table 10: Impact category descriptions and methodology

IMPACT CATEGORY (SHORT FORM)	IMPACT CATEGORY	UNITS	METHODOLOGY
LCIA Results			
GWP excl biogenic	Global Warming Potential (excl biogenic carbon)	kg CO2eq	IPCC AR5
ODP	Ozone Depletion Potential	kg CFC11eq	TRACI 2.1
AP	Acidification Potential	kg SO_2 eq	TRACI 2.1
EP	Eutrophication Potential	kg N eq	TRACI 2.1
SFP	Smog Formation Potential	kg O_3eq	TRACI 2.1
ADPf	Abiotic Resource Depletion Potential of Non-renewable (fossil) energy resources	MJ	CML 2013
Life Cycle Inventory Results: Resource Use			
RPRe	Renewable primary resources used as energy carrier (fuel)	MJ	ISO 21930
RPRm	Renewable primary resources with energy content used	MJ	ISO 21930
NRPRe	Non-renewable primary resources used as an energy carrier	MJ	ISO 21930
NRPRm	Non-renewable primary resources with content used energy as material	MJ	ISO 21930
SM	Secondary materials	kg	ISO 21930
RSF	Renewable secondary fuels	MJ	ISO 21930
NRSF	Non-renewable secondary fuels	MJ	ISO 21930
RE	Recovered energy	MJ	ISO 21930
FW	Use of net fresh water resources	m^3	ISO 21930
Life Cycle Inventory Results: Output Flows and Waste Categories			
HWD	Hazardous waste disposed	kg	ISO 21930

IMPACT CATEGORY (SHORT FORM)	IMPACT CATEGORY	UNITS	METHODOLOGY
NHWD	Non-hazardous waste disposed	kg	ISO 21930
HLRW	High-level radioactive waste, conditioned, to final repository	kg	ISO 21930
ILLRW	Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	ISO 21930
CRU	Components for re-use	kg	ISO 21930
MR	Materials for recycling	kg	ISO 21930
MER	Materials for energy recovery	kg	ISO 21930
EE	Recovered energy exported from the product system	MJ	ISO 21930
Carbon Emissions and Removals			
BCRP	Biogenic Carbon Removal from Product	kg CO_2	ISO 21930
BCEP	Biogenic Carbon Emission from Product	kg CO_2	ISO 21930
BCRK	Biogenic Carbon Removal from Packaging	kg CO_2	ISO 21930
BCEK	Biogenic Carbon Emission from Packaging	kg CO_2	ISO 21930
BCEW	Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	kg CO_2	ISO 21930
CCE	Calcination Carbon Emissions	kg CO_2	ISO 21930
CCR	Carbonation Carbon Removals	kg CO_2	ISO 21930
CWNR	Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	kg CO_2	ISO 21930

It shall be noted that the above impact categories represent impact potentials, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) actually follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the functional unit (relative approach). LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

5.1. Life Cycle Impact Assessment Results

The potential environmental impacts associated with the installed roofing membrane are presented in Table 11 for the production, construction, and EoL stages.

Table 11: North American Impact Assessment Results

IMPACT CATEGORIES	UNIT	PRODUCTION (A1-A3)	TRANSPORT TO THE BUILDING SITE (A4)	CONSTRUCTION AND INSTALLATION (A5)	DECONSTRUCTION (C1)	TRANSPORT TO WASTE PROCESSING (C2)	WASTE PROCESSING (C3)	DISPOSAL (C4)	TOTAL

IMPACT CATEGORIES	UNIT	PRODUCTION (A1-A3)	TRANSPORT TO THE BUILDING SITE (A4)	CONSTRUCTION AND INSTALLATION (A5)	DECONSTRUCTION (C1)	TRANSPORT TO WASTE PROCESSING (C2)	WASTE PROCESSING (C3)	DISPOSAL (C4)	TOTAL
GWP excl biogenic	kg CO_2 eq	3.06E+00	9.79E-02	2.55E+00	0.00E+00	1.32E-01	0.00E+00	4.85E-01	6.32E+00
ODP	kg CFC11 eq	1.11E-10	1.93E-16	3.29E-13	0.00E+00	2.60E-16	0.00E+00	1.53E-14	1.12E-10
AP	kg SO_2 eq	1.06E-02	3.03E-04	5.49E-03	0.00E+00	4.08E-04	0.00E+00	2.08E-03	1.89E-02
EP	kg N eq	4.67E-04	3.13E-05	3.54E-04	0.00E+00	4.21E-05	0.00E+00	1.16E-04	1.01E-03
SFP	kg O_3 eq	1.36E-01	7.00E-03	1.53E-01	0.00E+00	9.42E-03	0.00E+00	3.65E-02	3.42E-01
ADPf	MJ	1.55E+02	1.43E+00	1.93E+02	0.00E+00	1.92E+00	0.00E+00	7.11E+00	3.59E+02

* The GWP indicator result is calculated based on IPCC AR5 method, ADPf indicator is based on CML 2013 (University of Lieden, 2013) method, while the rest of the indicators are based on TRACI 2.1 method.

5.2. Life Cycle Inventory Results

The resource consumption associated with the installed roofing membrane is presented in Table 12 for the production, construction, and EoL stages. Rainwater is not blue water and is therefore not included in the water consumption metric.

Table 12: Resource Use

RESOURCE INDICATORS	UNIT	PRODUCTION (A1-A3)	TRANSPORT TO THE BUILDING SITE (A4)	CONSTRUCTION AND INSTALLATION (A5)	DECONSTRUCTION (C1)	TRANSPORT TO WASTE PROCESSING (C2)	WASTE PROCESSING (C3)	DISPOSAL (C4)	TOTAL
RPRe	MJ	4.46E+00	5.60E-02	1.54E+00	0.00E+00	7.54E-02	0.00E+00	6.82E-01	6.81E+00
RPRm	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRPRe	MJ	1.59E+02	1.44E+00	1.94E+02	0.00E+00	1.94E+00	0.00E+00	7.27E+00	3.64E+02
NRPRm	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SM	kg	1.02E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-03
RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m^3	9.78E-03	2.01E-04	7.86E-03	0.00E+00	2.71E-04	0.00E+00	1.04E-03	1.92E-02

The waste generation associated with the installed roofing membrane are presented in Table 13 for the production, construction, and EoL stages.

Table 13: Output Flows and Waste Categories

OUTPUT AND WASTE	UNIT	PRODUCTION (A1-A3)	TRANSPORT TO THE BUILDING SITE (A4)	CONSTRUCTION AND INSTALLATION (A5)	DECONSTRUCTION (C1)	TRANSPORT TO WASTE PROCESSING (C2)	WASTE PROCESSING (C3)	DISPOSAL (C4)	TOTAL
HWD	kg	5.04E-09	5.98E-12	2.72E-09	0.00E+00	8.06E-12	0.00E+00	2.72E-10	8.04E-09
NHWD	kg	1.33E-01	0.00E+00	9.51E-01	0.00E+00	0.00E+00	0.00E+00	1.13E+01	1.24E+01
HLRW	kg	1.44E-06	4.73E-09	5.23E-07	0.00E+00	6.37E-09	0.00E+00	7.27E-08	2.04E-06
ILLRW	kg	1.21E-03	3.98E-06	4.53E-04	0.00E+00	5.37E-06	0.00E+00	6.37E-05	1.74E-03
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MR	kg	2.02E-03	0.00E+00	5.06E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.26E-02
MER	kg	2.03E-04	0.00E+00	2.30E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.32E-02
EE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

The carbon emission and removals associated with the installed roofing membrane are presented in Table 14 for the production, construction, and EoL stages.

Table 14: Carbon Emissions and Removals

PARAMETER	UNIT	PRODUCTION (A1-A3)	TRANSPORT TO THE BUILDING SITE (A4)	CONSTRUCTION AND INSTALLATION (A5)	DECONSTRUCTION (C1)	TRANSPORT TO WASTE PROCESSING (C2)	WASTE PROCESSING (C3)	DISPOSAL (C4)	TOTAL
BCRP	kg CO_2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BCEP	kg CO_2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BCRK	kg CO_2	2.44E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.44E-02
BCEK	kg CO_2	0.00E+00	0.00E+00	1.71E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.71E-01
BCEW	kg CO_2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CCE	kg CO_2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CCR	kg CO_2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CWNR	kg CO_2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

6. LCA Interpretation

The results represent the cradle-to-gate, construction and disposal environmental performance of the evaluated roofing membrane. As shown in the tables above, the results indicate that most of the impacts are driven by the product stage (modules A1- A3) and by construction stage (module A4 - A5). GWP impacts are contributed the maximum by raw materials and the installation process accounting for 42% and 40% respectively. Raw materials also contributes the most to AP and EP (51% and 41% respectively). The significant SFP and ADPf impacts come from the installation process again (45%, and 54% respectively).

Figure 6 represents the contribution analysis of the individual processes within each life cycle stage. As it is observed, the raw materials (A1) have greater contribution (41% to 53%) on all categories except for SFP and ADPf, which is mainly caused by the installation (A5) process (45% and 54% respectively). Besides SFP and ADPf indicators, installation (A5) also makes a significant contribution to all other categories except ODP, and ranges between 29% and 40%. Furthermore, manufacturing (A3) contributes 5% and 2% to GWP and AP respectively. Disposal (C2) makes its largest contribution to AP and EP (11% each). Transport (A2, A4 and C2) does not make a significant contribution to any of the categories (ranges from 1% to 3%).

More detailed contribution analysis was also done to determine the contributions of different materials and energy sources to the overall life cycle impacts. The results of such a contribution analysis can be found in the background LCA report. It is important to note that the results presented in this EPD and interpretations are based on the methodological approaches and assumptions taken from the the PCR. The transportation distances from manufacturing facility to construction site and from construction site to disposal, and the energy requirements for installation and deconstruction procedures are as per section 3.10 of the Part B PCR (ULE, 2021)

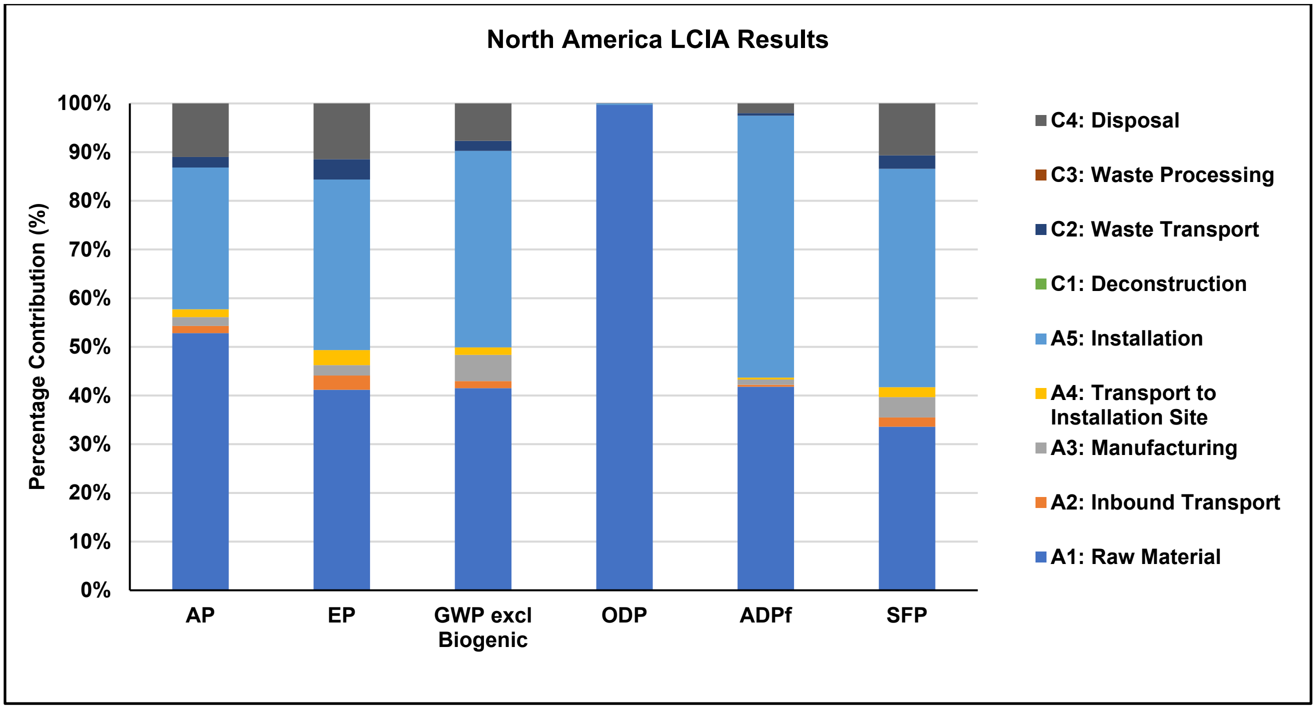

Figure 6: Contribution analysis of North American LCIA Results

The system results presented here do not represent the entire asphalt roofing industry, but only a specific type of asphalt roofing systems as specified in Table 1.

The accuracy of results is limited by the assumptions used in this study, specifically around the effective coverage and installation of the roofing systems under study. Results are based on the effective coverage values that were calculated from inputs provided by industry experts. These values might vary between participating members and might affect the overall cradle-to-gate results.

The installation and transport assumptions mentioned in the PCR can also influence the results associated with these stages.

7. Additional Environmental Information

7.1. Reflective Roofs

Reflective roofs are defined as roofing products with high solar reflectance. Many in the construction industry define "cool roofs" as roofing products with high solar reflectance and high thermal emittance. Asphalt-based products have the inherent property of having high emittance, regardless of their reflective properties. Asphaltic roof systems typically have thermal emittance values greater than 0.80. Reflectance is a deliberate product characteristic, and varies based on the surfacing used.

There are reflective roof options available for virtually any roof and any building. Because of asphalt roofs' longevity, asphalt-based products provide excellent value for homeowners and building owners by delivering superior durability and sustainability at reasonable cost.

Modified bitumen membranes provide options for varying levels of reflectivity. The reflectivity is related to the color of the modified bitumen membrane surface, surfacing material, or field applied coating. While reflective roofs are an increasingly popular roof option, they represent one of many approaches to help building owners and consumers reduce building energy use and address contemporary environmental concerns.

7.2. Individual Component Results

Table 15 presents non-zero cradle-to-gate results for environmental impacts, resource use, output flows and waste, and carbon emissions and removals associated with each individual component of the built-up asphalt roofing system. It should be noted that the impacts presented in Table 15 are for production stage (A1-A3) only and do not include impacts associated with construction (A4-A5) and EoL stages (C1-C4).

Table 15: Production stage (A1-A3) impact results for each system component, per 1 m^2 of individual component

IMPACT CATEGORY	UNITS	CAP SHEET	BASE SHEET	PLY FELTS	TOTAL (A1-A3)
Impact Assessment					
GWP excl biogenic	kg CO_2 eq	1.41E+00	8.71E-01	7.71E-01	3.06E+00
ODP	kg CFC11 eq	6.14E-11	3.40E-11	1.58E-11	1.11E-10
AP	kg SO_2 eq	4.67E-03	3.47E-03	2.46E-03	1.06E-02
EP	kg N eq	2.12E-04	1.47E-04	1.08E-04	4.67E-04
SFP	kg O_3 eq	6.27E-02	3.76E-02	3.53E-02	1.36E-01
ADPf	MJ	6.29E+01	3.85E+01	5.39E+01	1.55E+02
Resources Use					
RPRe	MJ	2.04E+00	1.21E+00	1.21E+00	4.46E+00
NRPRe	MJ	6.43E+01	3.96E+01	5.46E+01	1.59E+02
SM	kg	5.61E-04	3.11E-04	1.44E-04	1.02E-03
FW	m3	4.73E-03	3.02E-03	2.02E-03	9.78E-03

Output Flows and waste Categories					
HWD	kg	2.07E-09	1.29E-09	1.68E-09	5.04E-09
NHWD	kg	4.05E-02	7.97E-02	1.25E-02	1.33E-01
HLRW	kg	6.31E-07	5.05E-07	3.01E-07	1.44E-06
ILLRW	kg	5.37E-04	4.24E-04	2.54E-04	1.21E-03
MR	kg	2.81E-04	1.74E-03	0.00E+00	2.02E-03
MER	kg	0.00E+00	2.03E-04	0.00E+00	2.03E-04
Carbon Emissions and Removals					
BCRK	kg	9.27E-03	5.55E-03	9.59E-03	2.44E-02

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9. Contact Information

Study Commissioner

ASPHALT ROOFING MANUFACTURERS ASSOCIATION

Asphalt Roofing Manufacturers Association,
2331 Rock Spring Road,
Forest Hill, MD 21050
https://www.asphaltroofing.org/contact-us/

LCA Practitioner

sphera™

Sphera Solutions, Inc.
130 E Randolph St, #2900
Chicago, IL 60601
https://sphera.com/contact-us/
www.sphera.com