Environmental Product Declaration

Asphalt Shingle Roofing System

INSTALLATION: FASTENED

Steep-slope roofing system installed with fasteners and consisting of asphalt shingl underlayment, leak barrier, starter strip, and hip and ridge components.

ATLAS

certainteed SAINT-GOBAIN

GAF

IKO

OWENS CORNING

PABCO Roofing Products

TAMKO BUILDING PRODUCTS LLC

ASPHALT ROOFING MANUFACTURERS ASSOCIATION

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.

UL 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	4789862118.111.2
DECLARED PRODUCT & FUNCTIONAL UNIT OR DECLARED UNIT	1 m^2 of Asphalt Shingle Roofing System (Installation: Fastened)
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	Asphalt Shingle Roofing System (Installation: Fastened)
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 Professional) (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
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

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.

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:

Atlas
www.atlasroofing.com

CertainTeed
www.certainteed.com

GAF
www.gaf.com

IKO
www.iko.com

Owens Corning
www.owenscorning.com

PABCO
www.pabcoroofing.com

TAMKO Building Products LLC
www.tamko.com

2.2. Product Description

The steep-slope roofing system included in this study consists of laminated/multilayered asphalt shingles, underlayment, leak barrier, starter strip, and hip and ridge components.

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 shingles, underlayment, leak barrier, starter strip, and hip & ridge

COMPONENT	SPECIFICATION	DESCRIPTION
Asphalt shingles	ASTM D3018 Type I, D3462; CSA A123.5	- Asphalt shingles consist of fiberglass mat impregnated and coated on both sides with filled asphalt and surfaced on the exposed-to-weather portion with mineral granules. Asphalt shingles are self-sealing - Primary weather barrier
Underlayment	ASTM D226, D4869; CSA A123.3	- Underlayment consists of organic felt saturated with asphalt - Helps prevent moisture from penetrating to the roof structure

COMPONENT	SPECIFICATION	DESCRIPTION
Leak barrier	ASTM D1970; CSA A123.22	- Leak barriers consist of fiberglass mat impregnated and coated with polymer-modified asphalt - Helps prevent moisture from penetrating to the roof structure
Starter strip	ASTM D3018 Type I, D3462; CSA A123.5	- Starter strips consist of fiberglass mat impregnated and coated with asphalt - Creates a starter row when first installing roofing system. Starter strips are self-sealing - Provides double layer coverage for first course and 2-inch headlap, and helps prevent wind blow-off of shingles
Hip and ridge	ASTM D3018 Type I, D3462; CSA A123.5	- Hip and ridge shingles consist of fiberglass mat impregnated and coated with asphalt. Hip and ridge shingles are self-sealing - Installed on the hips and ridges of a steep-slope roof

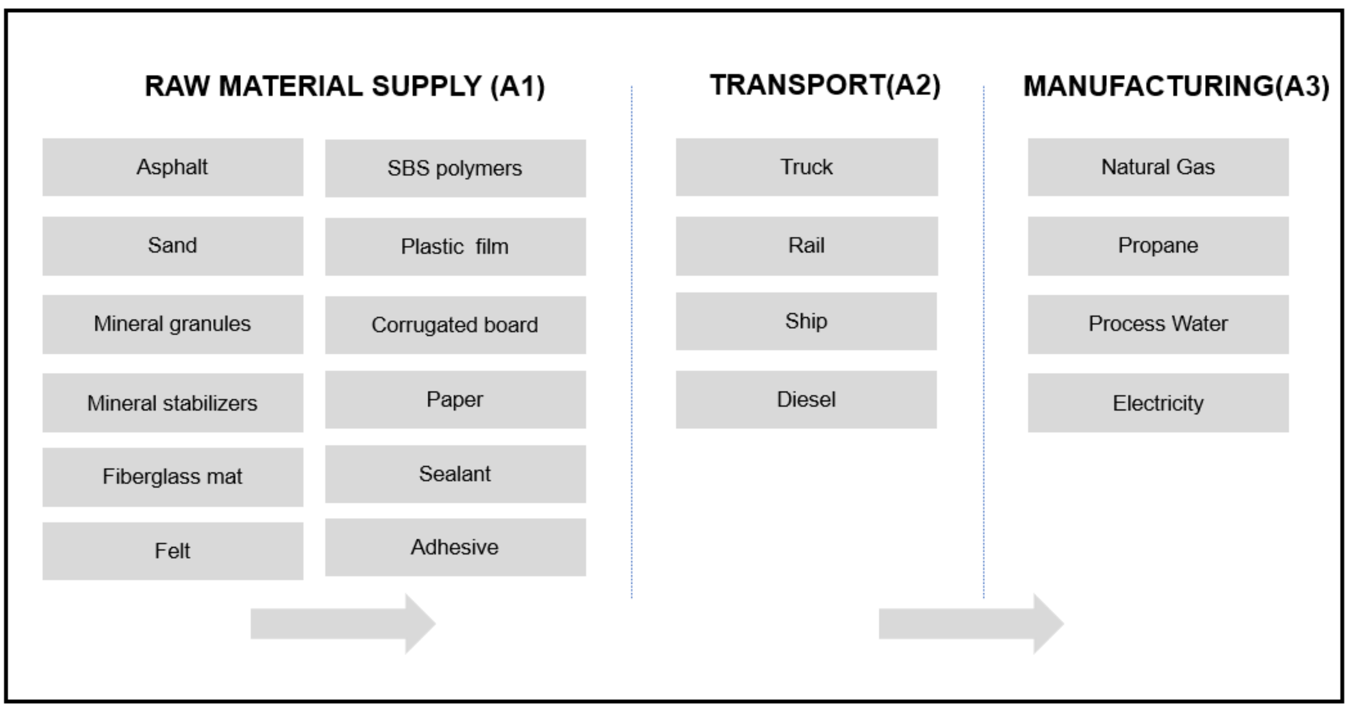

Figure 1: Production process overview

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 these products. A weighted average was then calculated based on each facility's production amounts in mass.

2.4. Application

Steep-slope roofing systems are installed on roofs with slope equal to or greater than 2:12. Steep-slope roofing systems are primarily used to protect residential and light commercial construction from the weather.

Asphalt shingles provide a winning combination of beauty, affordability and reliability. They are available in a variety of colors, textures and styles to fit many unique designs, and offer a long service life. Asphalt shingle roofing systems provide protection against wind, rain, snow and extreme temperatures.

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 asphalt shingle, underlayment, leak barrier, starter strip, and hip and ridge manufacturing

MATERIAL INPUTS	WEIGHT PERCENTAGE IN INDIVIDUAL COMPONENT
Asphalt Shingle (89% of representative roofing system)	
Mineral stabilizers	34%
Mineral granules	27%
Asphalt	18%
Headlap	11%
Sand	7%
Fiberglass mat	2%
Laminating adhesive	1%
Sealant	< 1%
Styrene butadiene styrene (SBS) polymer	<1 %
Underlayment (5% of representative roofing system)	
Organic felt (paper, cardboard)	47%
Asphalt	53%
Leak Barrier (2% of representative roofing system)	
Asphalt	43%
Mineral stabilizers	25%
Mineral granules	15%
Sand	6%
Fiberglass mat	5%
Styrene butadiene styrene (SBS) polymer	4%
Polyolefin film	2%
Starter Strip (1% of representative roofing system)	
Mineral stabilizers	36%
Mineral granules	29%

MATERIAL INPUTS	WEIGHT PERCENTAGE IN INDIVIDUAL COMPONENT
Asphalt	18%
Headlap	9%
Sand	5%
Fiberglass mat	2%
Sealant	<1%
Styrene butadiene styrene (SBS) polymer	<1%
Hip and Ridge (2% of representative roofing system)	
Mineral granules	35%
Mineral stabilizers	34%
Asphalt	18%
Headlap	7%
Sand	4%
Fiberglass mat	2%
Sealant	<1%
Styrene butadiene styrene (SBS) polymer	<1%

2.6. Technical Requirements

Table 3: Product ASTM International and CSA Group Specifications

PRODUCT CATEGORY	DESCRIPTION/SPECIFICATION
Asphalt shingles	ASTM D3018 Type I, D3462; CSA A123.5
Underlayment	ASTM D226, D4869; CSA A123.3
Leak barrier	ASTM D1970; CSA A123.22
Starter strip	ASTM D3018 Type I, D3462; CSA A123.5
Hip and ridge	ASTM D3018 Type I, D3462; CSA A123.5

2.7. Properties of Declared Product as Delivered

The Asphalt Shingle Roofing System products comply with one or more of ASTM D3018 Type I; D3462; CSA A123.5; ASTM D226, D4869; CSA A123.3; ASTM D1970; CSA A123.22; ASTM D3018 Type I, D3462; CSA A123.5; ASTM D3018 Type I, D3462; CSA A123.5.

3. Methodological Framework

3.1. Declared Unit

The declared unit of this study is 1 m^2 (10.8 ft^2) of the installed asphalt shingle roofing system. The associated reference flow (the quantity of material required to fulfill the declared unit) is 12.39 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 shingles, underlayment, leak barrier, starter strip, and hip and ridge asphalt shingle roofing system, 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			CONSTRUCT-ION 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 Managed LCA Content (formerly GaBi databases 2022) (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

Fiberglass Asphalt Shingle (laminated shingle, starter strip, and hip and ridge)

Manufacture of fiberglass asphalt shingles, starter strips, and hip and ridge shingles begins with impregnation and coating of a fiberglass mat with a filled asphalt coating. The filled coating mixture is produced in a separate process that involves mixing oxidized asphalt and mineral stabilizer in appropriate proportions. Colored mineral granules are added to the top surface on areas that will be exposed in the installed condition. Other granules, typically referred to as headlap granules, are added to the top surface of the impregnated fiberglass mat on areas that will not be exposed in the installed condition. A parting agent is added to the bottom surface to facilitate separation of the shingles during installation. An asphalt-based adhesive is applied to the finished shingle and serves to bond individual shingles to each other after installation. In the case of multi-layer shingles, the individual layers are combined during manufacturing using a laminating adhesive. Finally, the shingle is cut to size and packaged for shipment. The thickness of the wide variety of roofing shingles, starter strip shingles, and hip and ridge shingles on the market can vary substantially. Manufacturers do not report the thickness of any type of shingle.

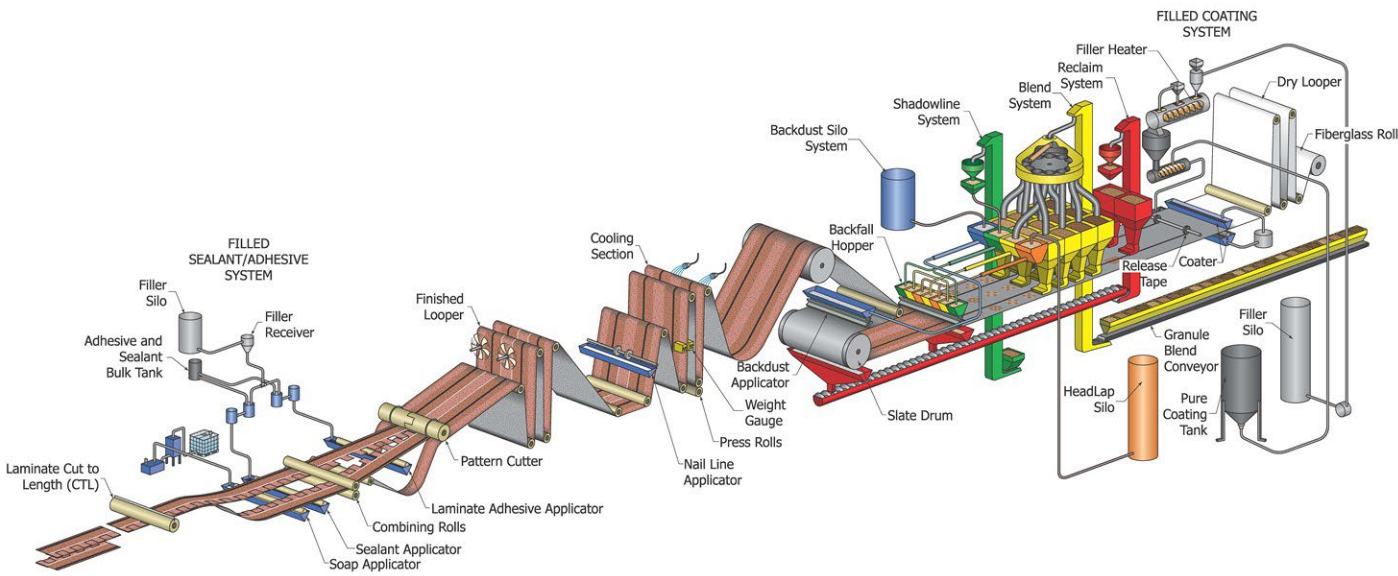

Figure 2: Laminate shingle production diagram

Underlayment (saturated organic felt)

Saturated organic felt underlayment manufacturing involves production of an organic felt mat that typically incorporates paper, cardboard, and sawdust. In a separate process, the organic felt mat is saturated with non-oxidized or lightly oxidized asphalt. The product is cooled and wound into rolls and packaged for shipment.

Leak Barrier

Leak barrier manufacture involves impregnating and coating a fiberglass mat with a polymer-modified asphalt. The polymer-modified asphalt is produced by mixing appropriate proportions of polymer, non-oxidized or lightly oxidized asphalt, and limestone or other suitable mineral stabilizer. A fine mineral or film surfacing is applied to one side and a removable release liner to the other side. Some products incorporate a narrow strip of permanently attached or removable film along one edge to facilitate connection to overlapping sheets during installation. The product is cooled, wound into rolls, and packaged for shipment.

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 the fact sheet from the EPA (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	12.39	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)		-

* 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, the installation of a steep-slope roofing system begins with the attachment of leak barrier at eaves and other locations where ice dams are likely. This is followed by the application of underlayment to the roof deck with approved fasteners. A starter strip is then fastened to the roof along the eave edge. Flashing and vents are installed as needed. Shingles are then installed with nails starting from the eave edge to the ridge of the roof. Finally, hip and ridge shingles are installed at hips and ridges.

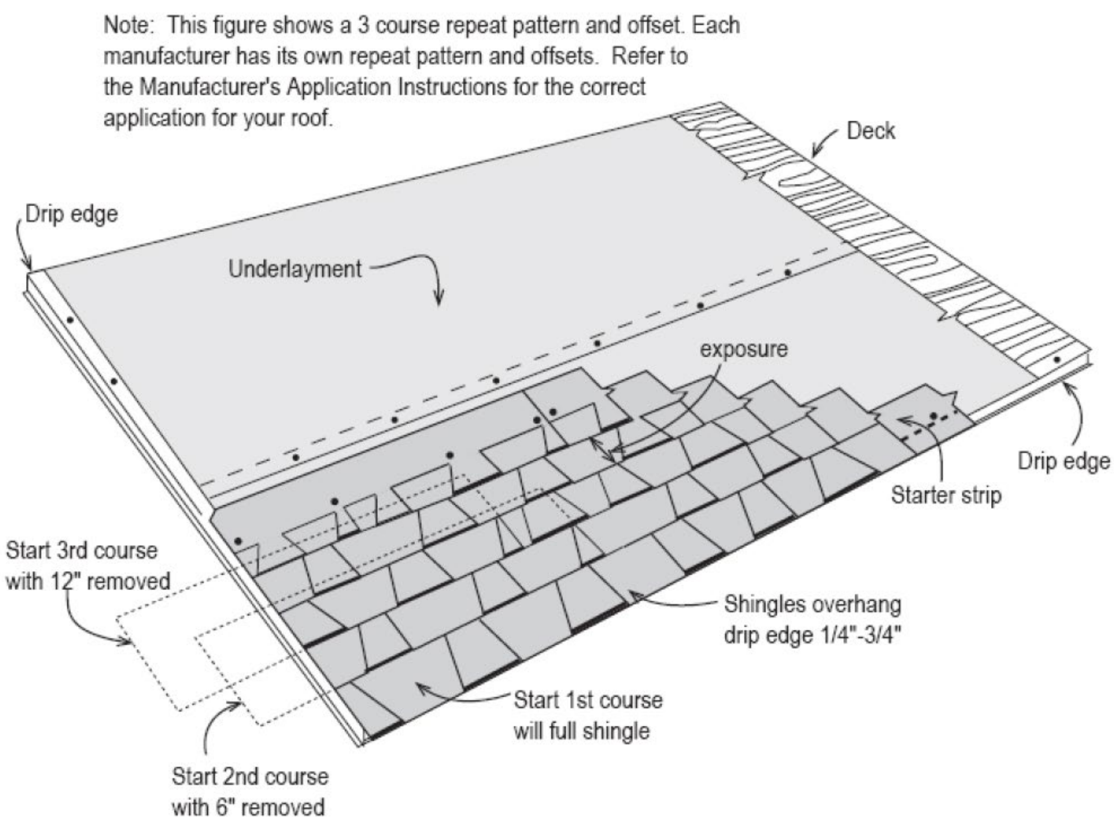

Figure 3: Asphalt shingle roofing system installation detail

Table 7: Installation into the building (A5)

NAME	VALUE	UNIT
Ancillary materials	0.21	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	-	MJ
Product loss per functional unit	0.23	kg
Waste materials at the construction site before waste processing, generated by product installation	0.29	kg

NAME	VALUE	UNIT
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	0.10	kg CO_2
Direct emissions to ambient air, soil and water	-	kg
VOC emissions	-	ug/m^3

Table 8 below lists components of a typical steep-slope system. The effective coverage includes the required overlap of sheets while the scrap rate accounts for material wasted during installation. Note that offsets and scrap rates differ by manufacturer and it is recommended to review their printed installation instructions prior to installation. More details on general steep-slope installation can be found in the ARMA Residential Asphalt Roofing Manual.

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
Inputs					
Shingles	4.67	2.35	2%	11.20	(Sphera, 2016)
Underlayment	0.60	1.08	0.25%	0.65	(Sphera, 2016)
Leak Barrier	1.89	0.10	1%	0.19	(Sphera, 2016)
Starter Strip	4.63	0.03	1%	0.14	(Sphera, 2016)
Hip and Ridge	7.51	0.03	1%	0.23	(Sphera, 2016)
Flashing	0.049	-	-	0.049	(Sphera, 2016)
Vents	0.098	-	-	0.098	(Sphera, 2016)
Nails	0.064	-	-	0.064	(Sphera, 2016)
Outputs					
Installed System				12.39	
Waste				0.23	

4.5. Disposal

At the end-of-life, the steep-slope asphalt shingle roofing system 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	12.39	kg
Recovery (specified by type)	Reuse		kg
	Recycling		kg
	Landfill	12.39	kg

NAME		VALUE	UNIT
	Incineration		kg
	Incineration with energy recovery		kg
	Energy conversion efficiency rate		
Disposal (specified by type)	Product or material for final deposal in landfill	12.39	kg
Removals of biogenic carbon (excluding packaging)		N/A	kg CO_2

5. Environmental Indicators Derived from LCA

Environmental Product Declarations (EPDs) created under different Product Category Rules (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 CO_2eq	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

IMPACT CATEGORY (SHORT FORM)	IMPACT CATEGORY	UNITS	METHODOLOGY
Life Cycle Inventory Results: Output Flows and Waste Categories			
HWD	Hazardous waste disposed	kg	ISO 21930
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 asphalt shingle roofing system 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
GWP excl biogenic	kg CO_2 eq	4.38E+00	1.53E-01	6.81E-01	0.00E+00	1.44E-01	0.00E+00	5.29E-01	5.88E+00
ODP	kg CFC11 eq	6.44E-09	3.01E-16	1.64E-13	0.00E+00	2.84E-16	0.00E+00	1.67E-14	6.44E-09
AP	kg SO_2 eq	1.42E-02	4.73E-04	1.62E-03	0.00E+00	4.46E-04	0.00E+00	2.27E-03	1.90E-02
EP	kg N eq	8.44E-04	4.88E-05	8.90E-05	0.00E+00	4.60E-05	0.00E+00	1.26E-04	1.15E-03
SFP	kg O_3 eq	1.85E-01	1.09E-02	2.46E-02	0.00E+00	1.03E-02	0.00E+00	3.99E-02	2.70E-01
ADPf	MJ	1.81E+02	2.23E+00	6.29E+00	0.00E+00	2.10E+00	0.00E+00	7.76E+00	2.00E+02

* GWP excl. biogenic is calculated using IPCC AR5 method, ADPf using CML 2013 (University of Lieden, 2013) method, and remaining indicators using TRACI 2.1 method.

5.2. Life Cycle Inventory Results

The resource consumption associated with the installed asphalt shingle roofing system 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	1.80E+01	8.72E-02	6.80E-01	0.00E+00	8.23E-02	0.00E+00	7.45E-01	1.96E+01
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	1.87E+02	2.24E+00	6.69E+00	0.00E+00	2.12E+00	0.00E+00	7.94E+00	2.06E+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	5.90E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.90E-02
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	3.43E-02	3.14E-04	3.58E-03	0.00E+00	2.96E-04	0.00E+00	1.14E-03	3.96E-02

The waste generation associated with the installed asphalt shingle roofing system is 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	2.81E-08	9.32E-12	1.19E-09	0.00E+00	8.80E-12	0.00E+00	2.98E-10	2.96E-08
NHWD	kg	2.76E-01	0.00E+00	9.10E-01	0.00E+00	0.00E+00	0.00E+00	1.24E+01	1.36E+01
HLRW	kg	2.49E-06	7.37E-09	1.19E-07	0.00E+00	6.96E-09	0.00E+00	7.94E-08	2.70E-06
ILLRW	kg	2.11E-03	6.21E-06	1.38E-04	0.00E+00	5.86E-06	0.00E+00	6.96E-05	2.33E-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	1.41E-01	0.00E+00	2.95E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.71E-01
MER	kg	5.15E-05	0.00E+00	1.43E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.43E-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	1.03E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E-02
BCEK	kg CO_2	0.00E+00	0.00E+00	9.90E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.90E-02
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 asphalt shingle roofing system. As shown in the tables above, the results indicate that the product stage (modules A1-A3) dominates the impacts across all categories, and construction stage (module A4 - A5) and end-of-life (EoL – C1 –

C4) contribute noticeable impacts across all categories.

Figure 4 represents the contribution analysis of the individual processes within each life cycle stage. As it is observed. the raw materials (A1) have greater than 60% contribution on all categories. Installation (A5) phase makes a noticeable contribution to all categories accounting for 3% to 12% except ODP. Furthermore, manufacturing (A3) contributes 11% and 8% to GWP and AP, respectively. Disposal (C4) makes its largest contribution to AP (12%) and SFP (15%). Inbound transportation (A2) during production stage also makes a small contribution to AP, EP and SFP indicators, ranging between 2% and 4%.

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).

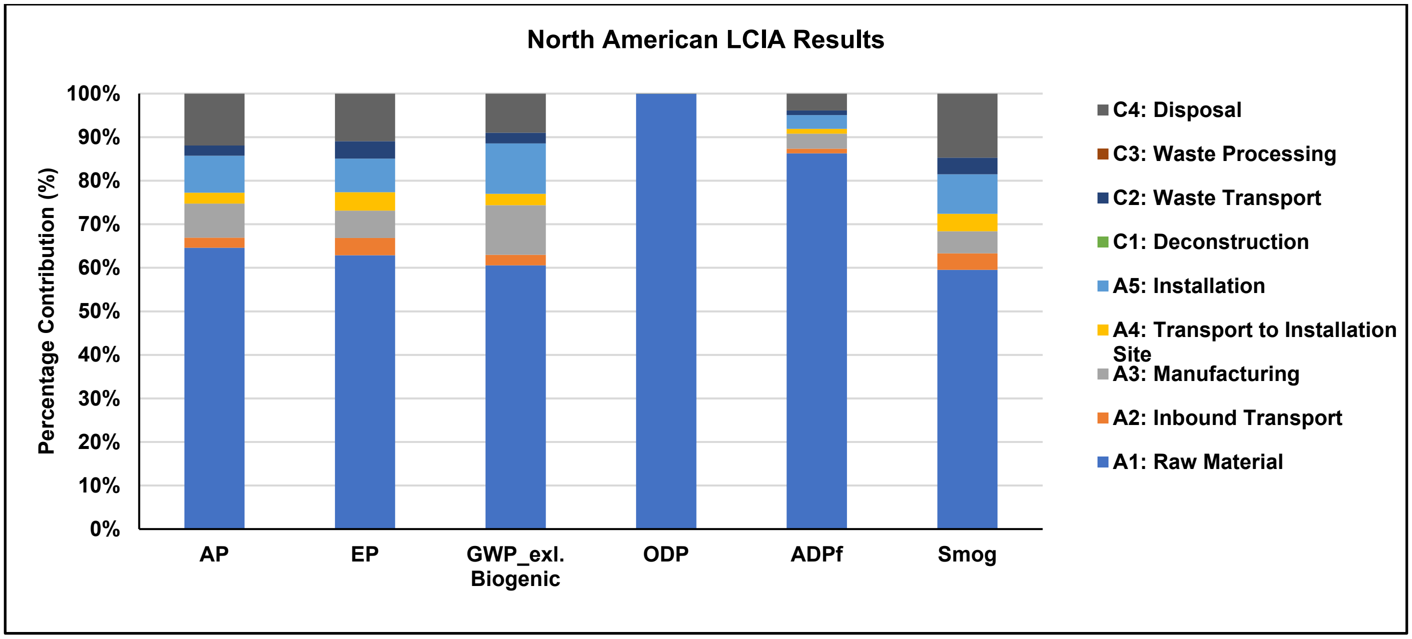

Figure 4: Contribution analysis of North American LCIA Results

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. Shingle Recycling and Incineration

Asphalt shingle recycling is economically viable, convenient where available, and saves valuable resources from being sent to a landfill. Asphalt shingle recycling can create jobs for recycling locations and reduce costs for products that utilize recovered materials. Recycling shingles also allows homeowners to make a positive environmental contribution.

Asphalt shingles are most commonly recycled into pavement, which offsets the need for new asphalt and aggregate. When recycled into pavement the shingles are ground and screened to remove any auxiliary debris, such as nails. The ground product is mixed with aggregate prior to being blended with virgin paving asphalt binder, thus displacing virgin asphalt binder and aggregate.

Uses beyond asphalt paving are developing, including use of recovered components into asphalt roofing and other products. Because these processes are new and emerging on a commercial scale during creation of this EPD, they are not accounted for in the LCA results presented in this EPD.

Due to inherent impurities, asphalt shingles cannot be combusted in standard incineration plants and thus are combusted in cement kilns, replacing alternative fuels such as refinery fuel gas.

7.2. 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. Asphalt 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.

Asphalt shingles provide options for varying levels of reflectivity. The reflectivity is related to the color of the asphalt shingles’ mineral granule surfaces. 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.

7.3. 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 steep slope 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	SHINGLES	HIP & RIDGE	LEAK BARRIER	STARTER STRIP	UNDERLAYMENT	TOTAL (A1-A3)
Impact Assessment							
GWP excl biogenic	kg CO_2 eq	3.61E+00	6.72E-02	1.18E-01	3.76E-02	5.45E-01	4.38E+00

Impact Category	Units	Shingles	Hip & Ridge	Leak Barrier	Starter Strip	Underlayment	Total (A1-A3)
ODP	kg CFC11 eq	1.69E-13	2.50E-15	3.19E-10	2.67E-15	6.12E-09	6.44E-09
AP	kg SO_2 eq	1.16E-02	2.02E-04	3.56E-04	1.12E-04	2.01E-03	1.42E-02
EP	kg N eq	5.77E-04	9.69E-06	2.07E-05	5.72E-06	2.32E-04	8.44E-04
SFP	kg O_3 eq	1.44E-01	2.75E-03	4.96E-03	1.57E-03	3.19E-02	1.85E-01
ADPf	MJ	1.49E+02	2.86E+00	5.51E+00	1.72E+00	2.25E+01	1.81E+02
Resources Use							
RPRe	MJ	5.66E+00	8.36E-02	1.54E-01	5.05E-02	1.21E+01	1.80E+01
NRPRe	MJ	1.53E+02	2.94E+00	5.64E+00	1.76E+00	2.34E+01	1.87E+02
SM	kg	0.00E+00	0.00E+00	2.93E-03	0.00E+00	5.61E-02	5.90E-02
FW	m3	1.53E-02	2.57E-04	6.65E-04	1.33E-04	1.80E-02	3.43E-02
Output Flows and Waste Categories							
HWD	kg	3.19E-09	5.51E-11	9.37E-11	5.07E-11	2.47E-08	2.81E-08
NHWD	kg	2.39E-01	1.43E-02	5.83E-03	5.76E-03	1.09E-02	2.76E-01
HLRW	kg	1.95E-06	3.45E-08	6.16E-08	1.99E-08	4.15E-07	2.49E-06
ILLRW	kg	1.67E-03	2.93E-05	5.19E-05	1.69E-05	3.49E-04	2.11E-03
MR	kg	1.40E-01	2.96E-04	0.00E+00	1.22E-03	0.00E+00	1.41E-01
MER	kg	4.82E-05	3.62E-08	3.22E-08	3.17E-06	0.00E+00	5.15E-05
Carbon Emissions and Removals							
BCRK	kg	1.05E-03	8.01E-05	8.91E-03	1.87E-04	8.70E-05	1.03E-02

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