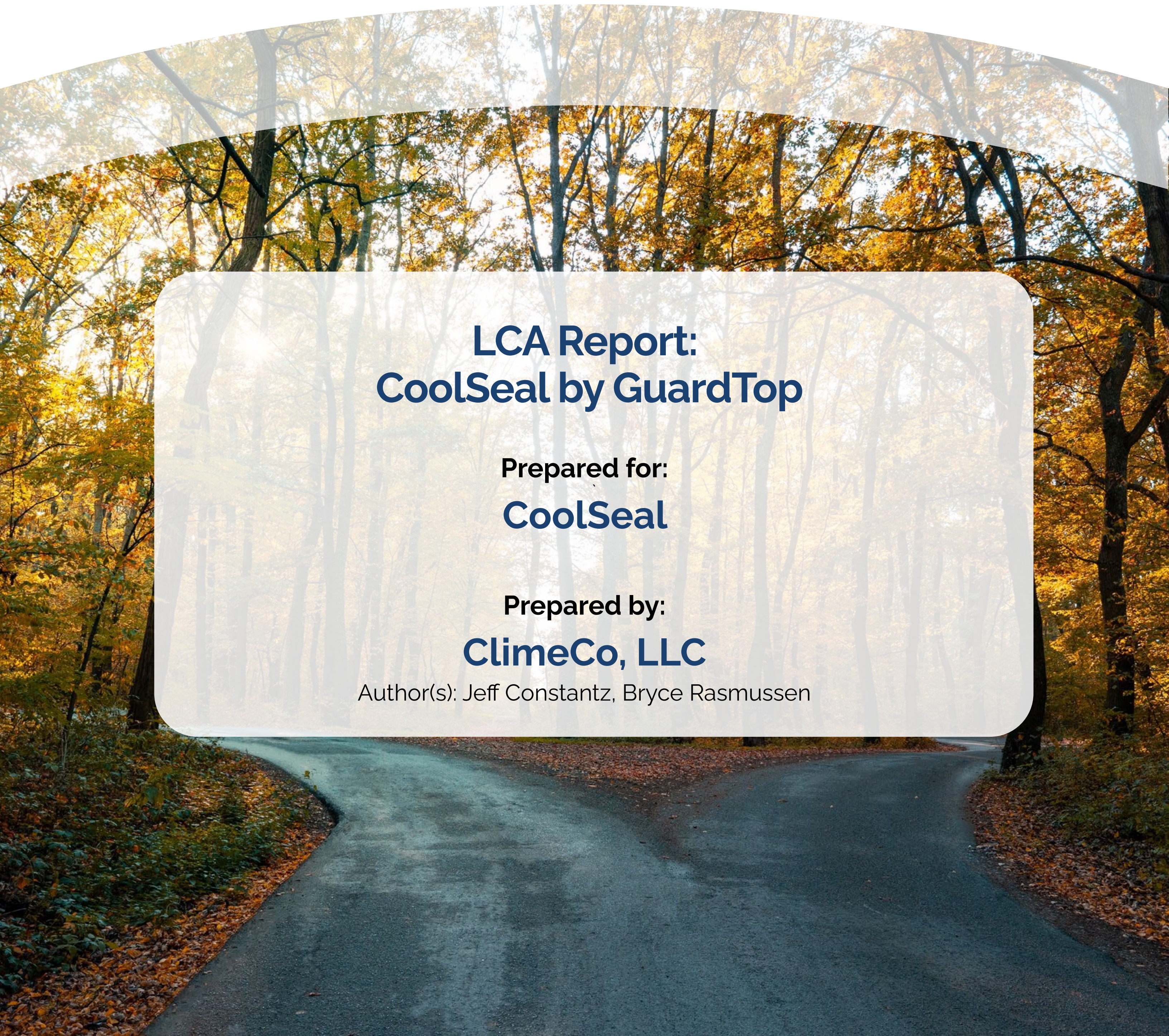
ClimeCo



LCA Report: CoolSeal by GuardTop

Prepared for:

CoolSeal

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Acronyms

AP	Acidification Potential
AR4	IPCC's Fourth Assessment Report
CFC-11	Trichlorofluoromethane
CI	Carbon Intensity
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalents
EF	Emission Factor
EP	Eutrophication Potential
g	Gram
GHG	Greenhouse Gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
Kg	Kilogram
kWh	Kilowatt Hour
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
LEED BD+C	Leadership in Energy and Environmental Design Building Design and Construction
MJ	Megajoule
N eq	Nitrogen Equivalents
ODP	Ozone Depletion Potential
O3e	Ozone Equivalents
PENRT	Total Use of Non-Renewable Primary Energy Resources

SFP	Smog Formation Potential
SO_2e	Sulfur Dioxide Equivalents

Naming Conventions

All references to the product throughout this report: GuardTop (parent company) CoolSeal will only be referred to in situations where activity data is aggregated at the parent company level (i.e. utility data from GuardTop prior to any allocation to CoolSeal)

Executive Summary

CoolSeal by GuardTop commissioned ClimeCo to conduct a cradle-to-gate Life Cycle Assessment (LCA) of modules A1 through A5 for a water-based asphalt emulsion sealcoat product. This report documents the analysis conducted, summarizing data and results for the CoolSeal product across the raw material production, raw material transportation, manufacturing, transportation to work sites and installation modules in conformance with the International Organization for Standardization (ISO) 14040 and 14044 [1] [2], and Product Category Rules for Building-Related Products and Services [3].

Founded in 1982, GuardTop emerged as a major player in the asphalt emulsions industry over several decades by acquiring other asphalt emulsion firms, cultivating diverse product offerings, and creating a strong, distinctive brand. Today, GuardTop is on a path for continued success, with an established presence in Arizona, California, and North Carolina. In the markets in which it operates, GuardTop's primary competitors include DuraShield by GAF Incorporated, and Plus Ti by Pavement Technology Incorporated.

With a suite of roadway sealcoat products, GuardTop's CoolSeal product is a high-performance water-based sealcoat designed to lower surface temperatures while extending the lifespan of asphalt pavement. As cities worldwide search for solutions to combat urban heat islands and reduce overall energy usage, CoolSeal has emerged as a promising technology for sustainable urban development. In recent years, the market for asphalt emulsion products like CoolSeal has seen significant growth as municipalities and property owners seek solutions to increase the lifespan of asphalt pavement while addressing other environmental burdens of sealcoat product lifecycles. The CoolSeal product represents a new generation of asphalt-based sealcoats designed to lower surface temperatures, extend the pavement life, and reduce the material, energy, and water inputs of sealcoat manufacturing. In 2023, the global asphalt emulsion market was valued at $100 billion, and projected to reach $134.01 billion by 2030 [3]. Within this growing market, products such as CoolSeal are creating a niche for environmentally sensitive asphalt products to play an important role in sustainable urban infrastructure projects.

This cradle-to-gate LCA aims to quantify the environmental impacts of CoolSeal throughout its lifecycle—from raw material extraction, transportation, manufacturing, and construction. In particular, the goal of this study was to quantify the environmental impact of CoolSeal on a square meter product basis. In this study, six LEED BD+C V4.1 impact categories were quantified, which include global warming potential (kg CO_2e), ozone depletion (kg CFC-11-eq), acidification (kg SO_2e), eutrophication (kg N-eq), tropospheric ozone (kg O_3e), and depletion of non-renewable energy resources (MJ).

The product system for the study was constructed based on CoolSeal production at GuardTop's manufacturing facility in Phoenix, Arizona. The manufacturing process is typical of sealcoat production, beginning with the raw materials procurement followed by materials blending until optimal consistency is achieved. Blending is closely monitored closely to avoid over-mixing. The finished product is finally loaded to a tanker truck for delivery to project sites.

The data for production and processing of CoolSeal was provided by the GuardTop team and corresponds to a 1,240,843 kg batch produced during the 2023 calendar year at their manufacturing location in Phoenix, Arizona. This primary data was supplemented with secondary datasets from the ecoinvent V3.10 EN15804GD database.

The product system boundaries for this analysis have been curtailed after the construction stage, excluding downstream activities such as use, end-of-life, and benefits and loads beyond the system boundary of the CoolSeal product. Consequently, this study comprehensively analyzed all life-cycle modules through the construction phase, including:

- A1 – Raw material supply
- A2 - Transport
- A3 - Manufacturing
- A4 - Transport to Site
- A5 – Assembly/Install

Based on the analysis, one square meter of CoolSeal yielded the results below for each impact category.

LEED BD+C 4.1 Impact Category	**Result**
Global Warming Potential	2.5858 kg CO_2e
Ozone Depletion	1.4714 x 10^{-7} kg CFC-11-eq
Acidification	0.01619 kg SO_2e
Eutrophication	0.01530 kg N eq
Tropospheric Ozone (Smog Formation Potential)	0.18442 kg O_3e
Depletion of Non-Renewable Energy Resources (PENRT)	43.216 MJ

Exhibit 1: Summary of Results for LEED BD+C 4.1 Impact Categories

This report and results are subject to an external third-party review by SCS Global Services to ensure the analysis findings are robust and objective.

1 Goal and Scope

1.1 Study Goal

This section provides details on what the analysis aimed to accomplish, the objectives of conducting the analysis, the audience for the results, and whether the study contents can be used in comparative assertions.

- Intended application: The intended application of the analysis was to determine the A1 through A5 environmental impact for six LEED V4.1 impact categories for CoolSeal, a water-based asphalt sealant product. Following a successful critical review of the study's results, subsequently develop a verified CoolSeal Environmental Product Declaration (EPD).
- Reasons for carrying out the study: To inform CoolSeal, their consumers, and other industry partners of the environmental impacts associated with the production and construction of the CoolSeal product through a verified EPD, and to help CoolSeal's customers earn 1.5 LEED BD+C product points.
- Intended audience: The intended audience of this LCA report is the SCS Global review team, while the results, to be disclosed through an EPD, are intended for business-to-business audiences.
- Public disclosure: The results are not intended to be used in comparative assertions[1].

1.2 Study Scope

This section describes the product system studied through the choice of declared unit, system boundary, life cycle impact assessment (LCIA) method, data representativeness and completeness, and sensitivity modelling approach for the system.

1.2.1 Declared Unit:

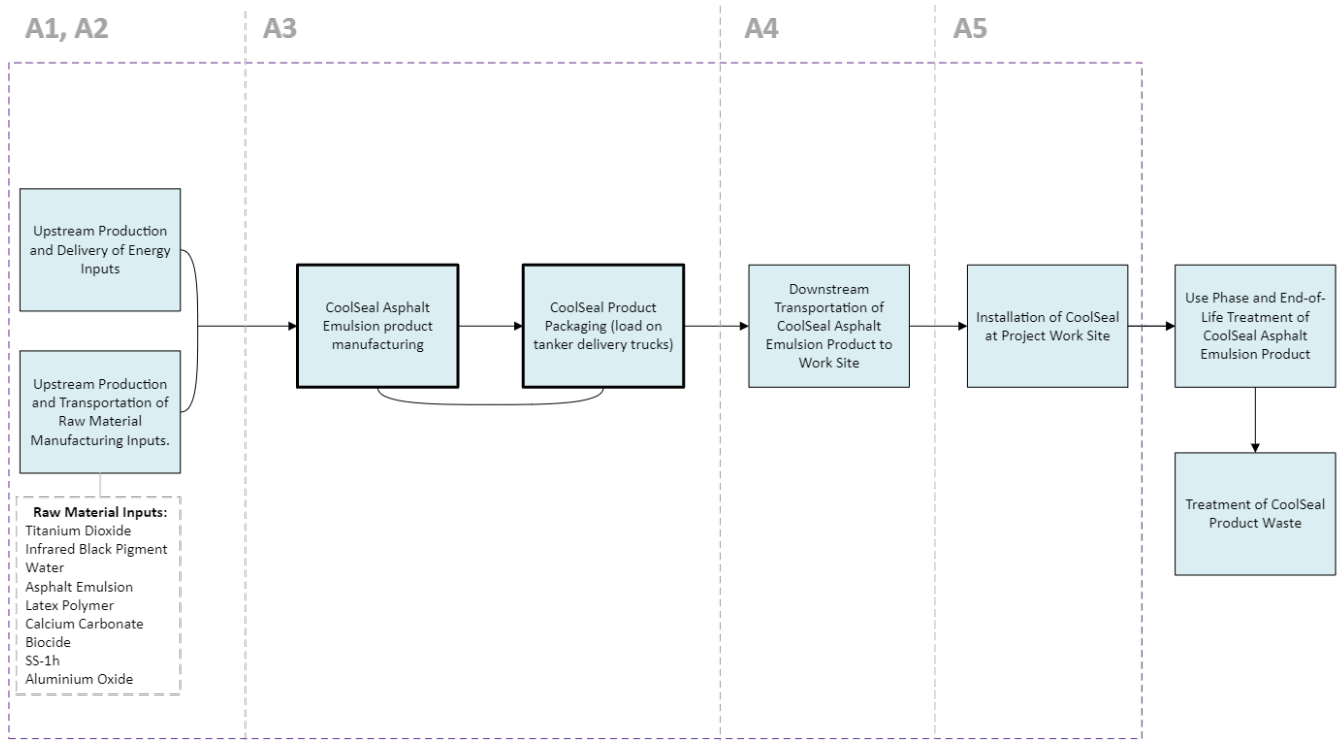
The primary function of the CoolSeal product is to offer a protective sealant to paved asphalt. In addition to providing a protective sealant, CoolSeal is used to reduce urban heat island effect. It is sold to municipalities, property owners, and contractors who then apply it to paved asphalt surfaces. Given the curtailed system boundary of this LCA, we have normalized the study's impacts to a declared unit of one square meter of asphalt emulsion sealcoat product.

1.2.2 System Boundary:

The analysis has been performed for life-cycle modules A1 through A5, with the system boundary curtailed after product installation, in line with the goal of the assessment. The defined boundary, shown in Exhibit 2

[1] The definition of a comparative assertion is as stated in ISO 14040:2006/14044:2006 [1] [2].

below, excluded the use-phase and end-of-life components of the product system, which were not considered in this analysis.



Note: The purple dotted line represents the system boundary

Exhibit 2: CoolSeal Asphalt Emulsion Sealcoat (1 m²) Product System Boundary

EPD Type	PRODUCTION			CONSTRUCTION		USE							END OF LIFE				BENEFITS & LOADS BEYOND 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 to site	Assembly/Install	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	Deconstruction	Transport	Waste processing	Disposal	Reuse, Recovery, Recycling Potential	Reference Service Life
Cradle to gate	*Required*					*Excluded*							*Required, depending on Section 2.8.4.5*				*Optional*	Optional
Cradle to gate with options	*Required*			*Optional*		*Ex.*	*Op.*	*Excluded*					*Optional*				*Optional*	Optional
Cradle to grave	*Required*																*Optional*	Required

Exhibit 3: System Boundary for EPD Type "Cradle to gate with options"

Within the defined A1 through A5 system boundary, the study applied a standard cut-off criterion, where any component contributing more than 1% to the overall impact was included. To that end, all inputs and outputs related to the production, packaging, transportation and installation of the CoolSeal product as shown above were considered in the study. Cut-off criterion excluded the impacts from mobile combustion associated with a medium-duty truck and passenger car at the manufacturing facility, and recycled packaging materials of the raw materials. Electricity impacts from air conditioning (A/C) at the manufacturing facility were excluded deeming A/C non-essential to the manufacturing process. The analysis addressed upstream impacts for all other included material and energy inputs, as well as end-of-life treatment impacts for waste outputs from the installation processes. No waste outputs are generated from the production processes. If a product batch does not meet the desired consistency standards it is blended into the succeeding batch.

An annual aggregate of material and energy flows into the system were provided by GuardTop CoolSeal. Overall, the system boundary comprehensively captured all impacts associated with the production of CoolSeal sealant product through product installation, and no known material, energy, or waste exclusions were made other than the aforementioned items.

1.2.3 Life Cycle Impact Assessment Method for Results Interpretation

As defined in the study goal, the analysis evaluated the product system in terms of six impact categories as required by LEED BD+C v4.1:

- global warming potential (kg CO_2e)

- ozone depletion (kg CFC-11-eq)
- acidification (kg SO_2e)
- eutrophication (kg N eq)
- tropospheric ozone (kg O_3e)
- depletion of non-renewable energy resources (MJ)

The limitations of this scope have been disclosed in the LCIA Results Limitations section of the report.

1.2.4 Data Representativeness

This sub-section discusses the details pertinent to the temporal, geographical, and technological representativeness of the data and assesses its reliability and applicability to the system under study.

Impact quantification for life cycle modules A1 through A5 of the CoolSeal product relied on primary facility-specific data whenever possible, while being supplemented by secondary datasets to assess upstream impacts from material and energy inputs.

- Primary data: Primary data predominantly reflected batch activity data in the CoolSeal processes, including:
    - Raw material input quantities for production,
    - CoolSeal production quantities
    - Energy input quantities for production,
    - Product transportation to construction sites
    - Energy input quantities for product installation processes
    - Product waste quantities from installation processes

- Secondary data: Data for quantifying the upstream impacts of most material and energy inputs, as well as waste outputs, were sourced from ecoinvent v3.10 EN15804GD, with priority given to those that most accurately represented the materials and processes analyzed.

Temporal Representativeness:

Primary Data: The primary data used in this analysis corresponded to the period between January 1, 2023, and December 1, 2023 by GuardTop.

Secondary Data: Used for upstream processes related to material and energy inputs, secondary data represented the most relevant and recent available datasets for modelling emissions. Specifically, the v3.10 EN15804GD 2023 version of the ecoinvent database was used for determining the upstream impacts of raw materials and energy. Please refer to section two for temporal details of specific datasets.

Geographical Representativeness:

Primary Data: Primary material, energy, and waste data used in this analysis corresponded to GuardTop CoolSeal's production facility in Phoenix, Arizona. Geography of the construction phase was limited to North America.

Secondary Data: Secondary data was prioritized for the highest degree of representativeness of geographical locality of the actual material or energy source.

The applied electricity emission factor is based on the Western Electricity Coordinating Council (WECC) regional entity in ecoinvent corresponding to Guardtop CoolSeal's Phoenix, Arizona manufacturing location.

Most emission factors for material inputs and outputs that relied on the ecoinvent database were representative of average production and end-of-life treatment processes in United States geographies. In cases where United States geographies were unavailable, the next best option was selected based on data availability in the database.

<u>Technological Representativeness:</u>

Primary Data: Data used for production and packaging processes were highly reflective of GuardTop's current CoolSeal production process.

- Primary material and energy input data, as well as waste output data, used in this analysis came directly from GuardTop's Phoenix, AZ production facility. The data gathered represents the production of a typical CoolSeal batch, which begins with the blending of polymers, asphalt materials, and mineral fillers. The blended solution is then enhanced with CoolSeal's unique reflective additives, before being filled directly into large tanker trucks for transportation to the job site.

Secondary Data: The selection of secondary data was done through a process that prioritized the representative technology type.

In the absence of technology specific information from suppliers, emission factors for material and energy inputs were pulled from the ecoinvent market-based datasets, accounting for different technology mixes in material and energy production. The study also used market-based transportation providers and the Western Electricity Coordinating Council as the electricity provider.

1.2.5 Data Completeness

As per ISO 14044:2006 [1], "…cut-off criteria are used in LCA practice to decide which inputs are to be included in the assessment, such as mass, energy, and environmental significance". Emission factors from ecoinvent had no known cut-off criterion. The study applied a standard cut-off criterion, where any component contributing more than 1% to the overall impact was included. This cut-off approach excluded impacts from mobile combustion at the manufacturing facility, and recycled packaging materials of the raw materials. Electricity impacts from air conditioning (A/C) at the manufacturing facility were excluded deeming A/C non-essential to the manufacturing process. No additional cut-off criteria were applied in the production of CoolSeal.

1.2.6 Allocation Procedure

The Phoenix, AZ manufacturing facility in which CoolSeal is produced is also used to produce another GuardTop product identified as TRMSS. All the provided data, except for electricity usage, was specific to CoolSeal, so allocation of the data was not necessary. Mass-based allocation was leveraged to isolate facility electricity usage specifically for CoolSeal's production. Also, the amount of electricity consumed for air conditioning the manufacturing facility was calculated and subtracted from the total amount of electricity spent on manufacturing GuardTop's products.

1.2.7 Sensitivity Analysis

The key assumed parameters were analysed through a sensitivity analysis to measure their impact on the study results. One area of known uncertainty in the product system was the assumed transportation distances for the following material flows:

- Customer product pick-up and transport to construction sites
- CoolSeal delivery to construction sites

CoolSeal provided transportation data estimates were subjected to a sensitivity check to quantify the relative impact of the data on results.

One-at-a-time sensitivity analysis was conducted by varying all the parameters individually to observe their impact on the individual product systems and the final study results. The results of the sensitivity analysis are presented in Section 2.4.

1.2.8 Type of Critical Review

SCS Global will perform the role of independent external reviewer/expert. The review will be performed at the end of the study.

2 Life Cycle Inventory Analysis

The main purpose of this section is to provide details on the inputs and outputs used in setting up the inventory for the quantification of the six LEED BD+C v4.1 impact categories for modules A1 through A5. This section also provides the results of the sensitivity analysis.

2.1 Modeling Platform

The analysis was carried out in openLCA software version 2.2.0. Primary data for CoolSeal was obtained from GuardTop CoolSeal's accounting data as provided. Secondary data and emission factors were pulled from the ecoinvent 3.10 EN1580GD database (2024) [3]. TRACI v2.1 was used as the impact assessment method.

The asphalt sealcoat product process was broken down into five primary modules:

Production	***Raw Material Acquisition (A1)***	Included upstream impacts needed to produce raw materials used during CoolSeal manufacturing.
	Raw Material Transportation (A2)	Included transportation impacts for the raw materials.
	Asphalt Sealant Manufacturing[2] (A3)	Included impacts from energy inputs during production.
Construction	***Transportation to Construction Sites (A4)***	Included impacts from customer tanker truck pickups from the Phoenix, Arizona CoolSeal manufacturing facility and CoolSeal tanker truck deliveries to customer construction sites.
	Installation (A5)	Included impacts from energy inputs during product installation.

Exhibit 4: Summary of Asphalt Emulsion Sealant (1 m²) Production Modules Boundary

The following sub-sections provide information on specific components of the product system.

2.2.1 CoolSeal Production

CoolSeal's manufacturing is a multi-step process that requires various material and energy inputs.

The overall purpose of the asphalt emulsion sealant production process is to create a high-albedo coating that can be applied to existing asphalt surfaces to reduce heat absorption, mitigate urban heat island effects, and

[2] Includes raw material and energy production and transportation

prolong the life of the paved surface. The manufacturing process for an asphalt emulsion sealcoat product begins with the selection of raw materials, including light-colored aggregates, reflective pigments, and a specially formulated asphalt emulsion base. Next, these components are blended in precise ratios to achieve optimal durability and reflectivity. Polymers and other additives are incorporated to enhance performance characteristics such as durability and adhesion.

Key features of CoolSeal's manufacturing process include using water-based asphalt emulsion instead of solvent-based products, incorporating light-colored pigments and reflective materials to achieve high albedo, and ensuring the final product meets Environmental Protection Agency (EPA) and LEED requirements of at least 33% reflectivity [9]. The result is a sealcoat that dries to a light gray matte finish, reduces glare while increasing reflectivity, and significantly reduces surface temperatures by 10-20˚F compared to traditional asphalt [9].

The energy inputs required for the CoolSeal manufacturing process include:

- Electricity: Electricity powers the mixing equipment machinery.

  Electricity is also consumed at the Phoenix facility to produce the TRMSS product, which is not included in this study. In this analysis, electricity usage was differentiated between the manufacturing of CoolSeal and TRMSS using mass-based allocation. Also, the amount of electricity consumed for air conditioning the manufacturing facility was calculated and subtracted from the total amount of electricity spent on manufacturing GuardTop's products. As indicated in previous sections of the report, the electricity emissions were based off the WECC electricity grid region of the United States, which encompasses Arizona.

The required material inputs for the production process include:

- Titanium Dioxide: Provides high reflectivity and opacity, contributing to the sealant's heat-reflective properties.
- Infrared Black Pigment: Darkens the product while maintaining high infrared reflectivity for heat management.
- Water: The emulsion base necessary for product application while providing environmental benefits.
- Asphalt Emulsion: Forms the core binding material, providing durability and weather resistance to the sealant.
- Latex Polymer: Enhances flexibility, adhesion, and durability of the sealant coating.
- Calcium Carbonate: A filler that improves strength.
- Biocide: Prevents microbial growth in the sealant during storage and following application.
- SS-1h: A specific type of slow-setting asphalt emulsion that provides bonding and curing properties.
- Aluminium Oxide: May be used as an abrasive additive to enhance skid resistance of the sealant surface.

The analysis relied on ecoinvent to quantify the upstream impacts associated with product material inputs. Exhibit 4 below summarizes the materials included in the analysis:

CoolSeal Material Inputs	**System Process Used**
Titanium Dioxide	Market Process for Titanium Dioxide
Infrared Black Pigment	Market Process for Ferrochromium, high ca-carbon (68% Chromium)
Water	Market Process for Tap Water
Asphalt Emulsion	Market Process for Bentonite
Latex Polymer	Market Process for Latex
Calcium Carbonate	Market Process for Calcium Carbonate, Precipitated
Biocide	Market Process for Pesticide, Unspecified
SS-1h*	Market Process for Bitumen
Aluminium Oxide	Market Process for Aluminium Oxide, Metallurgical

Exhibit 5: Product Material Input Modelling Proxies

Due to limited data availability within the ecoinvent database, proxy materials were necessary for infrared black pigment, biocide, and constituents in the SS-1h and emulsion feedstocks. Ferrochromium was selected to serve as a proxy for the infrared black pigment since it has similar physical properties. Pesticide was selected as a proxy for biocide since both materials share similar main ingredients. For asphalt emulsion, the proxy selected was bentonite, and for SS-1h the proxy selected was bitumen. The upstream impacts from the material inputs were quantified using the ecoinvent database.

GuardTop CoolSeal employs an efficient, package-less approach to meet final product distribution needs. CoolSeal sealant is efficiently transported in bulk via tanker trucks. This packaging strategy allows CoolSeal to cater to a wide range of customer requirements, from large municipal projects to smaller commercial or residential applications, while minimizing packaging waste.

2.2.2 CoolSeal Construction

CoolSeal is delivered via truck to project sites in two ways: the customer picks up the product from GuardTop CoolSeal's manufacturing facility, or GuardTop CoolSeal delivers the product to customer project sites. Project locations were limited to those located in North America in this study. GuardTop CoolSeal provided estimates for the average distance and number of trips in 2023 for both delivery scenarios. The analysis assumed an equal amount of CoolSeal product was delivered on each trip for both scenarios. A generic truck system process was selected as the transportation input in ecoinvent 3.10.

Transport Type	# of Trips (per year)	Average Distance (in km)
Product Delivery to Customer	45	30
Customer Pick-Up Product	22	45

Exhibit 6: Transportation to Construction Sites Data

CoolSeal is applied using trucks equipped with a computerized spray technology to deliver precise amounts of the product. The application trucks use two gallons of diesel fuel to install 21,000 kilograms of CoolSeal. Due to the application technology's efficiency, GuardTop CoolSeal conservatively estimated a product loss of 0.5% during the construction process stage in 2023.

2.3 Data Sources and Quality Assessment

As stated in the sections above, the study relied on different sources of data for various components of the analysis. Primary data was incorporated for life-cycle modules A1 through A3, and estimates were used for life-cycle modules A4 and A5. A comprehensive list of data sources used in the analysis are shown below:

Life-Cycle Stage	***Material or Energy Input***	***Source***	***Data Quality Assessment***
A1 & A2 – Raw Material Acquisition and Transportation	Aluminum Oxide	Measured data from GuardTop CoolSeal (2023)	(1, 1, 1)
	Asphalt Emulsion	Measured data from GuardTop CoolSeal (2023)	(1, 1, 1)
	Calcium Carbonate	Measured data from GuardTop CoolSeal (2023)	(1, 1, 1)
	Infrared Black Pigment	Measured data from GuardTop CoolSeal (2023)	(1, 1, 1)
	Latex Polymer	Measured data from GuardTop CoolSeal (2023)	(1, 1, 1)
	Biocide	Measured data from GuardTop CoolSeal (2023)	(1, 1, 1)
	SS-1h	Measured data from GuardTop CoolSeal (2023)	(1, 1, 1)

	Tap Water	Measured data from GuardTop CoolSeal (2023)	(1, 1, 1)
	Titanium Dioxide	Measured data from GuardTop CoolSeal (2023)	(1, 1, 1)
A3 – CoolSeal Manufacturing	Electricity used for facility and machinery	Calculated data from GuardTop CoolSeal (2023)	(1, 1, 1)
	Total CoolSeal Produced	Measured data from GuardTop CoolSeal (2023)	(1, 1, 1)
	Total TRMSS Produced	Measured data from GuardTop CoolSeal (2023)	(1, 1, 1)
A4 – Transportation to Worksite	Kilometers of CoolSeal Transportation (truck, road)	Calculated data from GuardTop CoolSeal (2023)	(1, 1, 1)
A5 – CoolSeal Installation	Diesel for CoolSeal Installation On-Site	Calculated data from GuardTop CoolSeal (2023)	(1, 1, 1)

Exhibit 7: Data Sources

Material or Energy Input	***Notes***	***Source***	***Data Quality Assessment***
Aluminium Oxide	Average global production excluding Europe	ecoinvent 3.10 (RoW geography)	(1,4,1)
Asphalt Emulsion	Average global production	ecoinvent 3.10 (GLO geography)	(1,5,3)
Calcium Carbonate	Average global production excluding Europe	ecoinvent 3.10 (RoW geography)	(1,4,1)
Infrared Black Pigment	Average global production	ecoinvent 3.10 (GLO geography)	(1,5,4)

Latex Polymer	Average global production excluding Europe	ecoinvent 3.10 (RoW geography)	(1,4,1)
Biocide	Average global production	ecoinvent 3.10 (GLO geography)	(1,5,2)
SS-1h	Average global production	ecoinvent 3.10 (GLO geography)	(1,5,3)
Tap Water	Average global production excluding Europe	ecoinvent 3.10 (RoW geography)	(1,4,1)
Titanium Dioxide	Average global production excluding Europe	ecoinvent 3.10 (RoW geography)	(1,4,1)
Electricity	Average production in the Western United States	ecoinvent 3.10 (US-WECC geography)	(1,1,1)
Diesel	Average global production	ecoinvent 3.10 (GLO geography)	(1,5,1)

Exhibit 8: ecoinvent Inputs

The data quality from the individual data sources was assessed in terms of their temporal, geographical, and technological representatives (in order). NETL's Data Quality Index (DQI) methodology was used as the basis to assign scores for the three categories.

The data gathered was compiled from a combination of GuardTop CoolSeal measured data, ClimeCo calculations, and the ecoinvent v3.10 database. A description of each of these sources has been provided below:

Primary Data:

- Measured Data: This data was collected from GuardTop CoolSeal's production facility through calendar year 2023. Specifically, the data for electricity was acquired from the production facility's utility bills, while quantities of material inputs were acquired through a combination of metering devices and accounting records.
- Calculated data: Calculations were performed by ClimeCo to determine the amount of electricity used for air conditioning and the production of GuardTop CoolSeal's TRMSS product. CoolSeal performed basic calculations to estimate average transportation distances of the CoolSeal product from the exit of the manufacturing facility gate to construction sites in 2023. CoolSeal also calculated how much diesel was used in 2023 to install the product.

Secondary data:

- ecoinvent: The ecoinvent v3.10 database was used to calculate emission factors for the above documented material and energy inputs. The database was accessed through openLCA 2.2.0. ecoinvent is listed as an acceptable database to use in the Product Category Rules for Building Related Products and Services [3].

2.4 Results of Sensitivity Analysis

One-at-a-time sensitivity analysis was conducted by varying the following parameters specified in section 1.2.7 of the report:

- Client product pick-up transportation distances to construction sites
- CoolSeal product delivery transportation distances to construction sites

The transportation distance values were altered individually by subjecting them to a 100% increase, while maintaining all other parameters at their expected values. The results of the study changed by less than 1% when varying the selected parameters, demonstrating the minimal impact of the assumptions on the results.

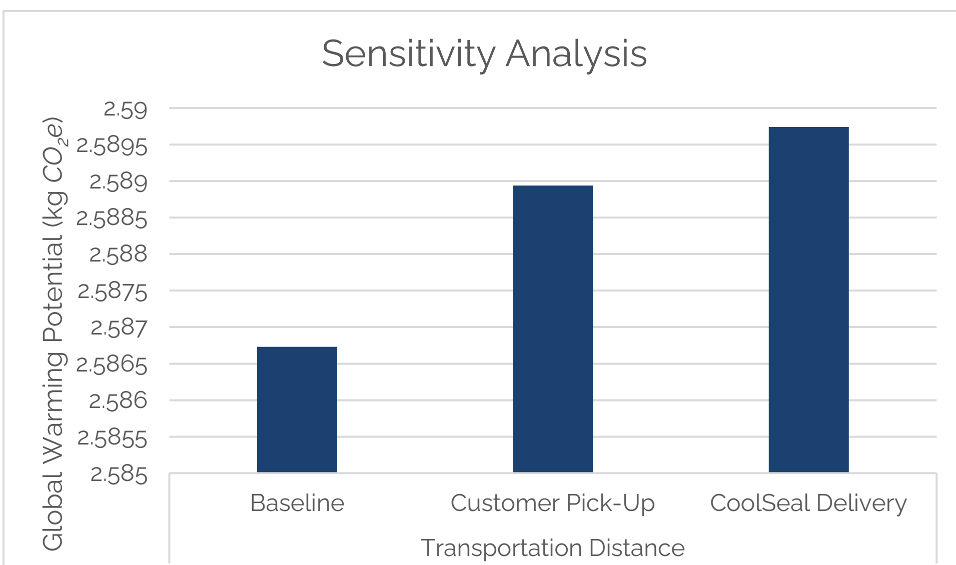


Exhibit 9: Global Warming Potential (kg CO_2e) Sensitivity Analysis Results

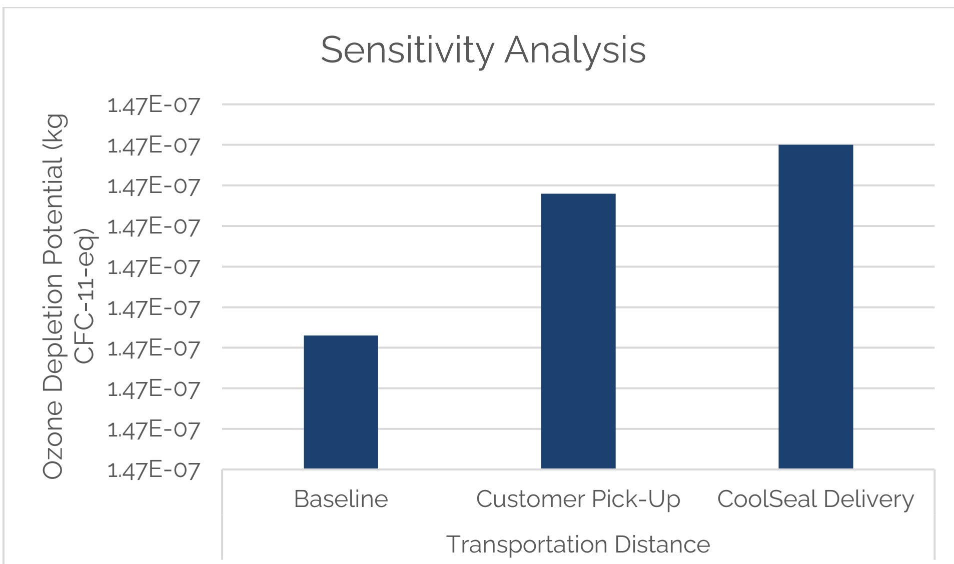


Exhibit 10: Ozone Depletion Potential (kg CFC-11-eq) Sensitivity Analysis Results

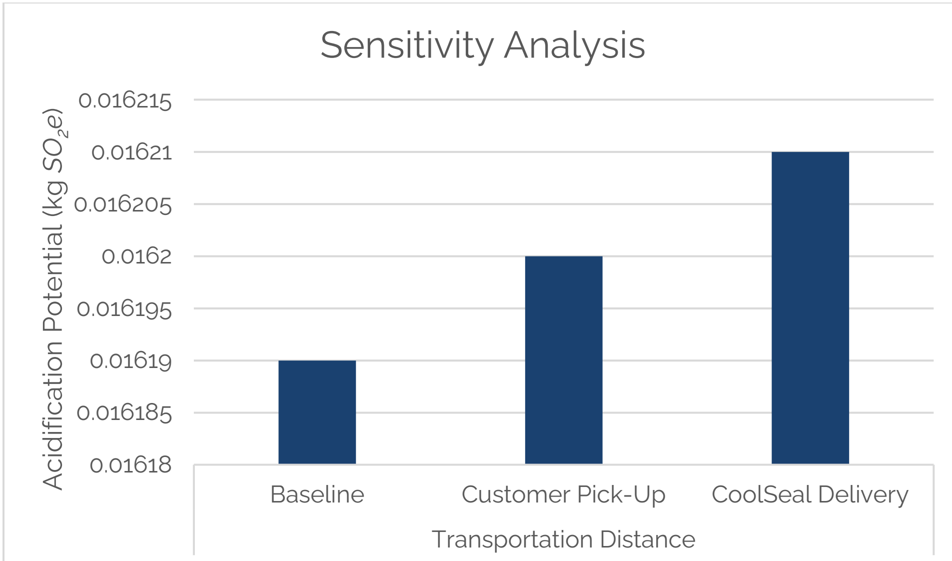


Exhibit 11: Acidification Potential (kg SO_2e) Sensitivity Analysis Results

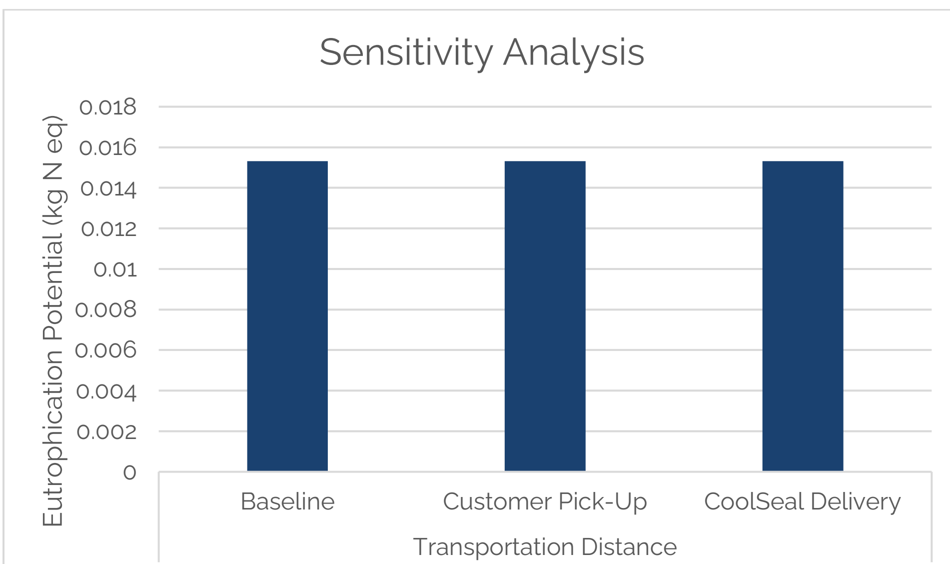


Exhibit 12: Eutrophication Potential (kg N eq) Sensitivity Analysis Results

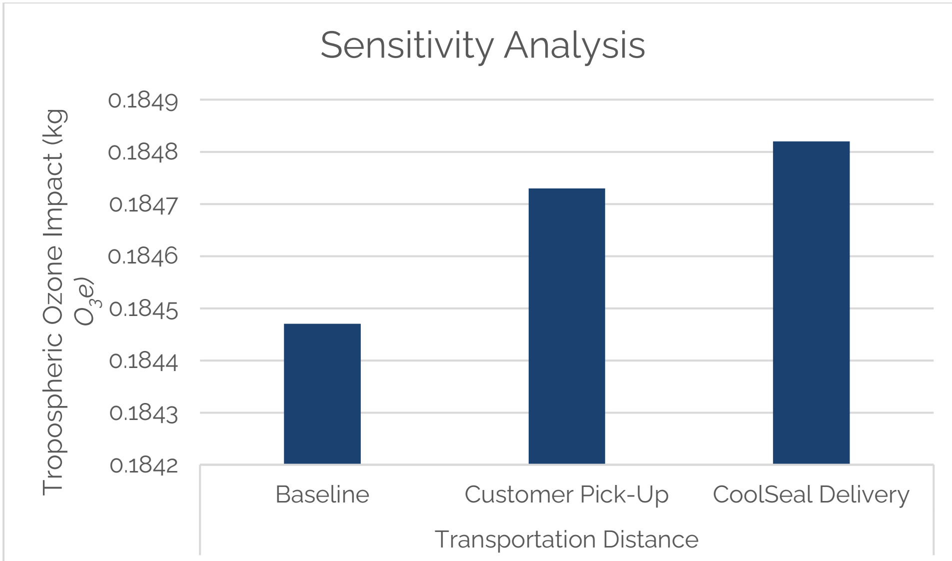


Exhibit 13: Tropospheric Ozone Impact (kg O_3e) Sensitivity Analysis Results

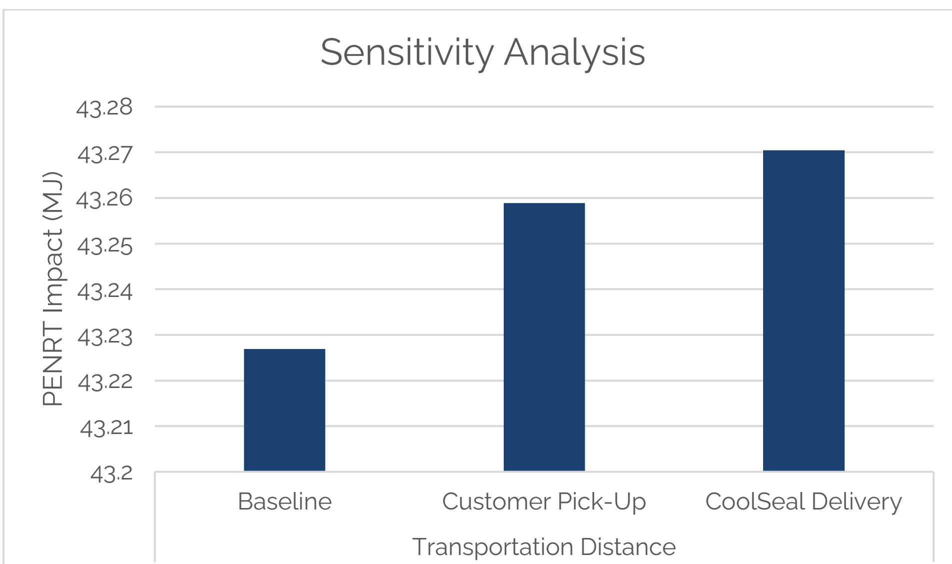


Exhibit 14: PENRT Impact (MJ) Sensitivity Analysis Results

2.5 Allocation Procedures

Allocation was avoided when possible. All data except electricity was specific to CoolSeal. Mass-based allocation was used to differentiate energy used for manufacturing CoolSeal versus the TRMSS product. Electricity consumed for air conditioning at the manufacturing facility was calculated and subtracted from the total amount of electricity consumed manufacturing both GuardTop products.

3 Life Cycle Impact Assessment

This section provides information on the life cycle assessment method used in the analysis. In addition, the section documents the LCIA results for the selected impact categories.

3.1 Life Cycle Impact Method for Results Interpretation

The goal of the study was to quantify the impacts in the six LEED V4.1 impact categories for A1 through A5 modules of the CoolSeal product. The quantified results will inform GuardTop CoolSeal, their consumers, and other industry partners of the Global Warming Potential (GWP), Ozone Depletion Potential (ODP), Acidification Potential (AP), Eutrophication Potential (EP), Smog Formation Potential (SFP), and Total Use of Non-Renewable Primary Energy Resources (PENRT) impacts from manufacturing and applying the CoolSeal product.

SFP is synonymous with the tropospheric ozone LEED4.1 impact category, and PENRT is synonymous with the depletion of non-renewable energy resources LEED 4.1 impact category.

LEED BD+C 4.1 Impact Category	Units
Global Warming Potential	kg CO_2e
Ozone Depletion	kg CFC-11-eq
Acidification	kg SO_2e
Eutrophication	kg N eq
Tropospheric Ozone (Smog Formation Potential)	kg O_3e
Depletion of Non-Renewable Energy Resources (PENRT)	MJ

Exhibit 15: List of Impact Categories and their Respective Units

GHG emissions were calculated, using 100-year global warming potentials based on IPCC's Fourth Assessment Report (AR4) [7]. The study neither assessed the impact of GHGs using Global Temperature Potential (GTP) nor other time horizons for GWPs.

All relevant emissions to the boundary were included in the impact quantification as summarised in the sections above.

3.2 Life Cycle Impact Assessment Results

The global warming potential impacts for CoolSeal's manufacturing and construction stage inputs within the product system (modules A1 through A5) are summarized in Exhibit 6 below based on the referenced flow of 1 m^2 CoolSeal:

Production Stage Material and Energy Inputs	***GWP Emissions (kg CO_2e)***
Electricity	0.03986
Asphalt Emulsion	0.00887
Aluminium Oxide	0.02514
Calcium Carbonate	0.02742
Infrared Black Pigment	0.19532
Latex Polymer	0.39194
Biocide	0.07253
Tap water	0.00012
Titanium Dioxide	1.53488
SS-1H	0.28365
Construction Process Stage Energy Inputs	***GWP Emissions (kg CO_2e)***
Road Transportation to Work Sites (Truck)	0.00523
Machine Operation, Diesel	0.00084

Exhibit 16: Categorized GWP Emissions Results for CoolSeal (1 m^2)

As demonstrated by the results above, most inputs and outputs had a nominal impact on the total emissions and impact result. Among all inputs and outputs, the top five contributors to the total, ranked in order, were:

- Titanium Dioxide – 1.53488 kg CO_2e /m^2 of CoolSeal
- Latex Polymer – 0.391940 kg CO_2e /m^2 of CoolSeal
- SS-1H – 0.283650 kg CO_2e /m^2 of CoolSeal
- Infrared Black Pigment – 0.195320 kg CO_2e /m^2 of CoolSeal
- Biocide – 0.072530 kg CO_2e /m^2 of CoolSeal

Together, these contributors accounted for 96% of the total modules A1 through A5 GWP for the CoolSeal (1 m^2) product.

The modules A1 through A5 ozone depletion impact for production process inputs within the product system have been summarized below in Exhibit 7 based on the declared unit of 1 m^2 CoolSeal:

Product Stage Material and Energy Inputs	***Ozone Depletion Impact (kg CFC-11-eq)***

Electricity	3.6459E-10
Asphalt Emulsion	1.36499E-10
Aluminium Oxide	1.224E-11
Calcium Carbonate	3.90400E-10
Infrared Black Pigment	1.04400E-09
Latex Polymer	2.12493E-10
Biocide	1.10739E-07
Tap water	2.67176E-11
Titanium Dioxide	2.32209E-08
SS-1H	1.08981E-08
Construction Process Stage Energy Inputs	***Ozone Depletion Impact (kg CFC-11-eq)***
Road Transportation to Work Sites (Truck)	8.139E-11
Machine Operation, Diesel	1.35931E-11

Exhibit 17: Categorized Ozone Depletion Impact Results for CoolSeal (1 m²)

As demonstrated by the results above, most inputs and outputs had a nominal impact on the total emissions and impact result. Among all inputs and outputs, the top five contributors to the total, ranked in order, were:

- Biocide – 1.10739E-07 kg CFC-11-eq /m^2 of CoolSeal
- Titanium Dioxide – 2.32209E-08 kg CFC-11-eq /m^2 of CoolSeal
- SS-1H – 1.08981E-08 kg CFC-11-eq /m^2 of CoolSeal
- Infrared Black Pigment – 1.04400E-09 kg CFC-11-eq /m^2 of CoolSeal
- Calcium Carbonate - 3.90400E-10 kg CFC-11-eq /m^2 of CoolSeal

Together, these contributors accounted for 99% of the total modules A1 through A5 ozone depletion for the CoolSeal (1 m^2) product.

The modules A1 through A5 acidification impact for CoolSeal's production process inputs within the product system have been summarized below in exhibit 8 based on the declared unit of 1 m^2 CoolSeal:

Product Stage Material and Energy Inputs	***Acidification Impact (kg SO_2e)***
Electricity	7.59837E-05
Asphalt Emulsion	5.88649E-05
Aluminium Oxide	0.00017

Calcium Carbonate	0.00015
Infrared Black Pigment	0.0008
Latex Polymer	0.00228
Biocide	0.00061
Tap water	5.33034E-07
Titanium Dioxide	0.01099
SS-1H	0.00103
Construction Process Stage Energy Inputs	***Acidification Impact (kg SO_2e)***
Road Transportation to Work Sites (Truck)	2.17523E-05
Machine Operation, Diesel	3.16023E-06

Exhibit 18: Categorized Acidification Impact Results for CoolSeal (1 m^2)

As demonstrated by the results above, most inputs and outputs had a nominal impact on the total emissions and impact result. Among all inputs and outputs, the top five contributors to the total, ranked in order, were:

- Titanium Dioxide – 0.01099 kg SO_2e /m^2 of CoolSeal
- Latex Polymer– 0.00228 kg SO_2e /m^2 of CoolSeal
- SS-1H – 0.00103 kg SO_2e /m^2 of CoolSeal
- Infrared Black Pigment – 0.0008 kg SO_2e /m^2 of CoolSeal
- Biocide – 0.00061 kg SO_2e /m^2 of CoolSeal

Together, these contributors accounted for 97% of the total modules A1 through A5 acidification for the CoolSeal (1 m^2) product.

The modules A1 through A5 eutrophication impact for CoolSeal's production process inputs within the product system have been summarized below in exhibit 9 based on the declared unit of 1 m^2 CoolSeal:

Product Stage Material and Energy Inputs	***Eutrophication Impact (kg N eq)***
Electricity	0.00027
Asphalt Emulsion	1.95175E-05
Aluminium Oxide	0.00011
Calcium Carbonate	6.81093E-05
Infrared Black Pigment	0.00073
Latex Polymer	0.0002

Biocide	0.00076
Tap water	4.56518E-07
Titanium Dioxide	0.01233
SS-1H	0.00081
Construction Process Stage Energy Inputs	***Eutrophication Impact (kg N eq)***
Road Transportation to Work Sites (Truck)	6.03052E-06
Machine Operation, Diesel	4.62742E-07

Exhibit 19: Categorized Eutrophication Impact Results for CoolSeal (1 m^2)

As demonstrated by the results above, most inputs and outputs had a nominal impact on the total emissions and impact result. Among all inputs and outputs, the top five contributors to the total, ranked in order, were:

- Titanium Dioxide – 0.01233 kg N eq /m^2 of CoolSeal
- SS-1H – 0.00081 kg N eq /m^2 of CoolSeal
- Biocide – 0.00076 kg N eq /m^2 of CoolSeal
- Infrared Black Pigment – 0.00073 kg N eq /m^2 of CoolSeal
- Electricity – 0.00027 kg N eq /m^2 of CoolSeal

Together, these contributors accounted for 97% of the modules A1 through A5 eutrophication for the CoolSeal (1 m^2) product.

The modules A1 through A5 tropospheric ozone (smog formation potential) impact for CoolSeal's production process inputs within the product system have been summarized below in exhibit 10 based on the declared unit of 1 m^2 CoolSeal:

Product Stage Material and Energy Inputs	***Tropospheric Ozone Impact (kg O_3e)***
Electricity	0.00133
Asphalt Emulsion	0.00134
Aluminium Oxide	0.0019
Calcium Carbonate	0.00242
Infrared Black Pigment	0.01087
Latex Polymer	0.03938
Biocide	0.00567
Tap water	7.58962E-06
Titanium Dioxide	0.10549

SS-1H	0.0153
Construction Process Stage Energy Inputs	***Tropospheric Ozone Impact (kg O_3e)***
Road Transportation to Work Sites (Truck)	0.00061
Machine Operation, Diesel	9.96917E-05

Exhibit 20: Categorized Tropospheric Ozone Impact Results for CoolSeal (1 m^2)

As demonstrated by the results above, most inputs and outputs had a nominal impact on the total emissions and impact result. Among all inputs and outputs, the top five contributors to the total, ranked in order, were:

- Titanium Dioxide – 0.10549 kg O_3e /m^2 of CoolSeal
- Latex Polymer – 0.03938 kg O_3e /m^2 of CoolSeal
- SS-1H – 0.0153 kg O_3e /m^2 of CoolSeal
- Infrared Black Pigment – 0.01087 kg O_3e /m^2 of CoolSeal
- Biocide – 0.00567 kg O_3e /m^2 of CoolSeal

Together, these contributors accounted for 96% of the modules A1 through A5 tropospheric ozone (smog formation potential) for the CoolSeal (1 m^2) product.

The modules A1 through A5 depletion of non-renewable energy resources (PENRT) impact for CoolSeal's asphalt sealcoat production process inputs within the product system have been summarized below in exhibit 11 based on the declared unit of 1 m^2 CoolSeal:

Product Stage Material and Energy Inputs	***PENRT Impact (MJ)***
Electricity	0.62961
Asphalt Emulsion	0.11301
Aluminium Oxide	0.24651
Calcium Carbonate	0.36145
Infrared Black Pigment	2.0717
Latex Polymer	12.19204
Biocide	1.09481
Tap water	0.00143
Titanium Dioxide	16.97913
SS-1H	9.43941
Construction Process Stage Energy Inputs	***PENRT Impact (MJ)***

Road Transportation to Work Sites (Truck)	0.07559
Machine Operation, Diesel	0.01103

Exhibit 21: Categorized Depletion of Non=Renewable Energy Resources (PENRT) Impact Results for CoolSeal (1 m²)

As demonstrated by the results above, titanium dioxide, latex polymer, and SS-1H accounted for most of the impacts. Among all inputs and outputs, the top five contributors to the total, ranked in order, were:

- Titanium Dioxide – 16.97913 MJ /m² of CoolSeal
- Latex Polymer – 12.19204 MJ /m² of CoolSeal
- SS-1H – 9.43941 MJ /m² of CoolSeal
- Infrared Black Pigment – 2.0717 MJ /m² of CoolSeal
- Biocide – 1.09481 MJ /m² of CoolSeal

Together, these contributors accounted for 97% of modules A1 through A5 depletion of non-renewable resources for the CoolSeal (1 m²) product.

It is worth noting that the LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

4 Life Cycle Interpretation

This section documents the interpretation of the life cycle assessment covering the environmental impacts of the analysed product system, the study limitations, conclusions, and recommendations. The results have been analyzed in the context of the goal and scope of the study.

4.1 Study Results

As per the goal of the study, GuardTop CoolSeal's Asphalt Sealcoat product was evaluated for modules A1 through A5 for global warming potential, ozone depletion, acidification, eutrophication, tropospheric ozone, and depletion of non-renewable energy resources. The exhibit below shows the emissions for the entire process, broken down by the primary life cycle modules as previously defined:

Modules	***Global Warming Potential (kg CO_2e/ m^2 CoolSeal)***
Raw Material Acquisition (A1)	2.49972
Raw Material Transportation (A2)	0.04015
Asphalt Sealant Manufacturing (A3)	0.03986
Transportation to Construction Sites (A4)	0.00523
Installation (A5)	0.00084

Exhibit 22: Table of Global Warming Potential Results by Life Cycle Stage

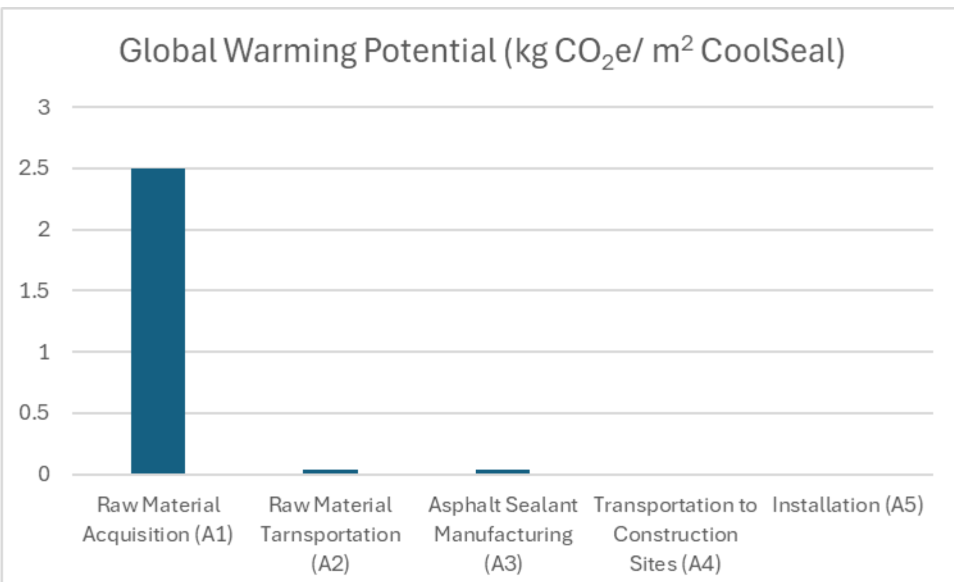


Exhibit 23: Graph of Global Warming Potential Results by Life Cycle Stage

Life Cycle Stage	*Ozone Depletion Impact (kg CFC-11-eq/ m² CoolSeal)*
Raw Material Acquisition (A1)	1.46467E-07
Raw Material Transportation (A2)	2.13594E-10
Asphalt Sealant Manufacturing (A3)	3.6459E-10
Transportation to Construction Sites (A4)	8.139E-11
Installation (A5)	1.35931E-11

Exhibit 24: Table of Ozone Depletion Results by Life Cycle Stage

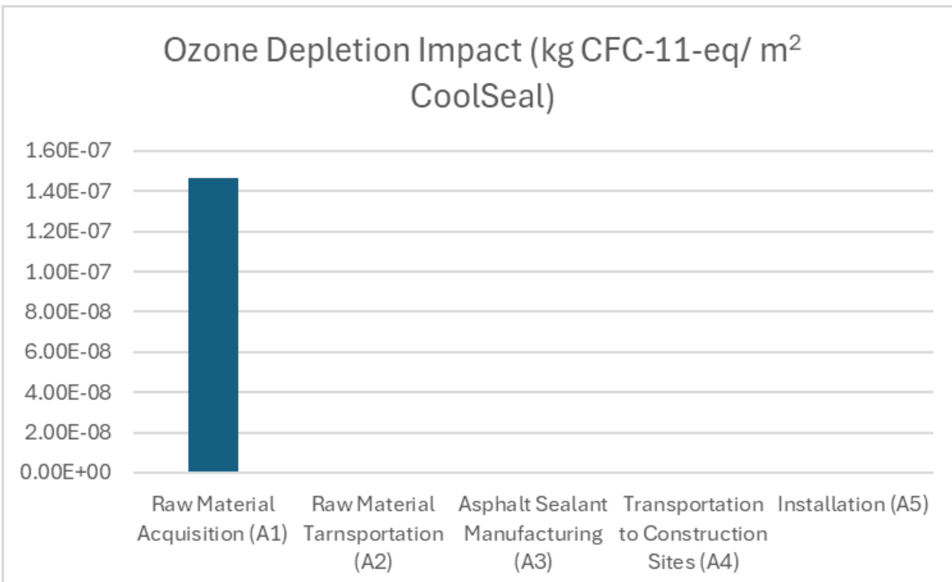


Exhibit 25: Graph of Ozone Depletion Results by Life Cycle Stage

Life Cycle Stage	*Acidification Impact (kg SO_2e/ m² CoolSeal)*
Raw Material Acquisition (A1)	0.015769645
Raw Material Transportation (A2)	0.000319753
Asphalt Sealant Manufacturing (A3)	7.59837E-05
Transportation to Construction Sites (A4)	2.17523E-05
Installation (A5)	3.16023E-06

Exhibit 26: Table of Acidification Results by Life Cycle Stage

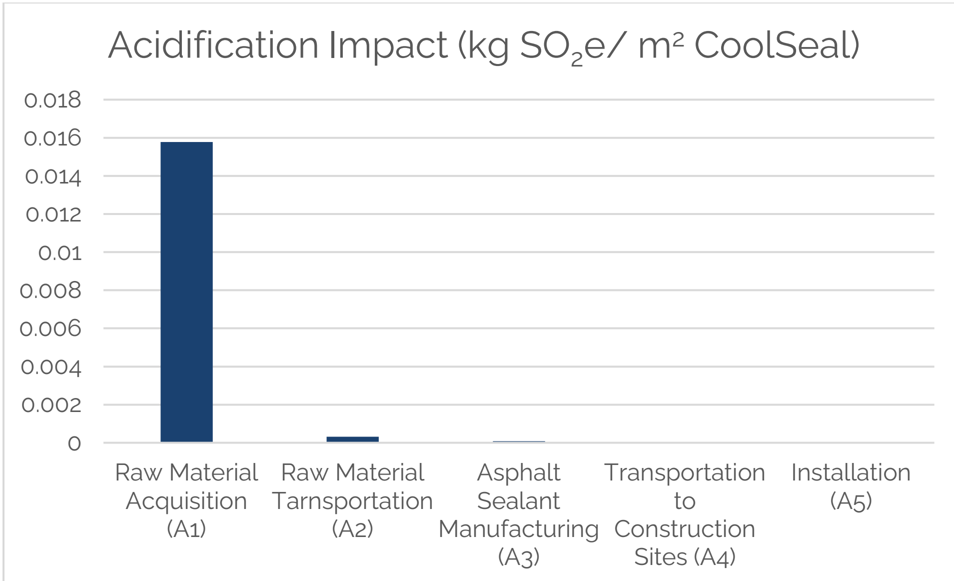


Exhibit 27: Graph of Acidification Results by Life Cycle Stage

Life Cycle Stage	***Eutrophication Impact (kg N eq/ m² CoolSeal)***
Raw Material Acquisition (A1)	0.014916149
Raw Material Transportation (A2)	0.000111935
Asphalt Sealant Manufacturing (A3)	0.00027
Transportation to Construction Sites (A4)	6.03052E-06
Installation (A5)	4.62742E-07

Exhibit 28: Table of Eutrophication Results by Life Cycle Stage

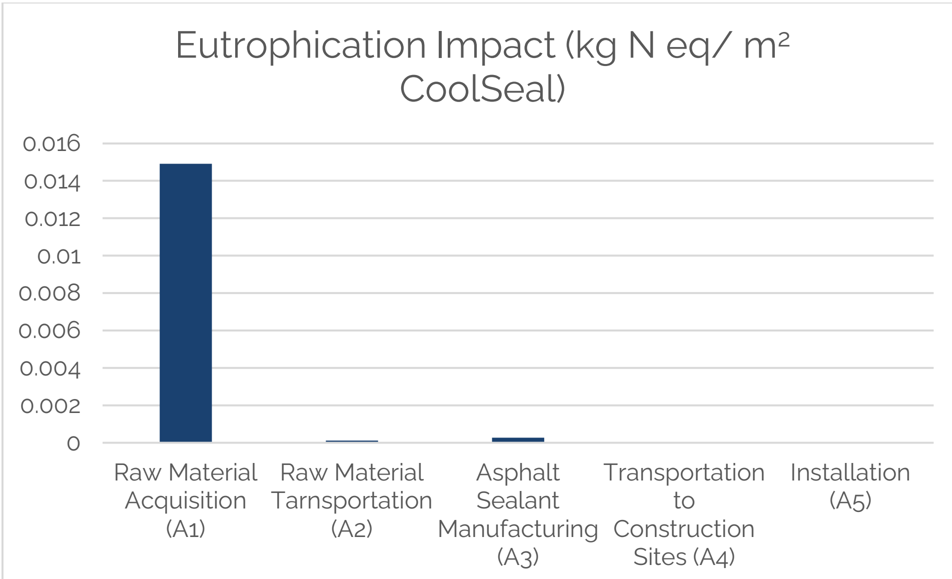


Exhibit 29: Graph of Eutrophication Results by Life Cycle Stage

Life Cycle Stage	***Tropospheric Ozone Impact (kg O_3e/ m^2 CoolSeal)***
Raw Material Acquisition (A1)	0.17458
Raw Material Transportation (A2)	0.00779759
Asphalt Sealant Manufacturing (A3)	0.00133
Transportation to Construction Sites (A4)	0.00061
Installation (A5)	9.96917E-05

Exhibit 30: Table of Tropospheric Ozone Results by Life Cycle Stage

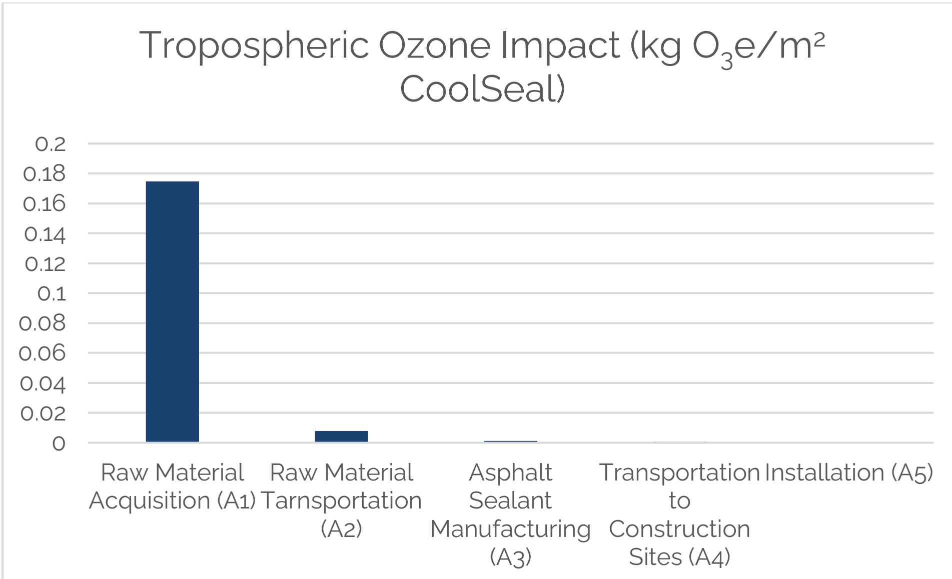


Exhibit 31: Graph of Tropospheric Ozone Results by Life Cycle Stage

Life Cycle Stage	***PENRT Impact (MJ/ m² CoolSeal)***
Raw Material Acquisition (A1)	41.89674
Raw Material Transportation (A2)	0.60275
Asphalt Sealant Manufacturing (A3)	0.62961
Transportation to Construction Sites (A4)	0.07559
Installation (A5)	0.01103

Exhibit 32: Table of PENRT Results by Life Cycle Stage

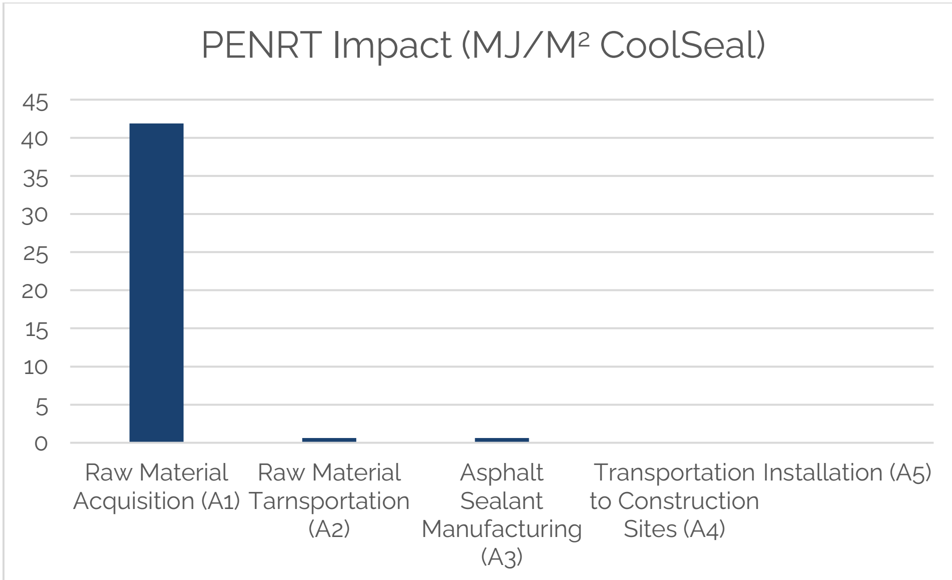


Exhibit 33: Graph of PENRT Results by Life Cycle Stage

4.2 LCIA Results Limitations

This study was specific to GuardTop's CoolSeal asphalt sealcoat product, so results should not be extrapolated to represent any other sealcoat products from other producers, as various components were specific to GuardTop's Phoenix, Arizona production facility. Further, this analysis consisted of modules A1 through A5, so the downstream impacts, including product use-phase, and end-of-life treatment, were not covered in the results of the analysis.

The primary data represented operational data for CoolSeal manufactured at GuardTop's CoolSeal Phoenix, Arizona facility during the period of January 1, 2023 – December 31, 2023. The results of the study may vary for a different study period or batch, due to variances in underlying parameters, such as total energy or material input requirements, or the temporal representativeness of emission factors used for modelling upstream impacts. Since GuardTop CoolSeal manufactures both CoolSeal and TRMSS products at the Phoenix facility, the exact amount of electricity used to manufacture CoolSeal was not available. To address this, the allocated amount of electricity to manufacture CoolSeal was based on a ratio of the mass of CoolSeal manufactured to the total mass of each product produced during the January 1, 2023 – December 31, 2023 period. Finally, while the best effort was made to obtain the most up-to-date and relevant secondary data points where needed, the use of secondary data is a recognized limitation. Ecoinvent v3.10 market processes were selected for all material and energy inputs, which represent an average of emissions data available. If an exact material input match in the ecoinvent v3.10 database was unavailable, the most similar available input was selected as proxy.

4.3 LCIA Evaluation

The modelling of the CoolSeal asphalt sealant product included all significant relevant processes and flows within the A1 through A5 system boundary modules and was thus designed to have a high level of completeness. The excluded items such as the manufacturing facility's mobile source and air conditioning energy inputs, raw material recycled packaging and international deliveries were expected to have immaterial impact on the study results.

For the product system, all data gathering, calculation, and modelling aimed for a consistent and repeatable methodology that represented all processes and inputs as close to the physical reality as possible. High-quality data gathering and thorough modelling of all relevant processes was performed consistently across the model, and conservative assumptions were used consistently when necessary. These assumptions were additionally subject to a sensitivity analysis to demonstrate their nominal impact on the six impact categories.

4.4 Recommendations

To improve the quality and consistency of this study in the future, there are several actions that could be taken. As highlighted in the results limitations section, secondary data can be improved by using primary sources of data, where possible. Collaborating with upstream suppliers would enable the collection of data specific to the actual material inputs, energy inputs, and waste treatment methods. This detailed understanding of inputs could better inform emission factor quantification for inputs and outputs.

4.5 Conclusion

The goal of this study was to quantify six LEED 4.1 impact categories of a GuardTop Coolseal asphalt emulsion sealcoat product from module A1 through module A5, quantifying impacts across raw material production, raw material transportation, manufacturing, construction transportation and installation modules in accordance with the International Organization for Standardization (ISO) 14040 and 14044 [1] [2]. This analysis was conducted with a combination of GuardTop CoolSeal-supplied primary data for the production material and energy inputs and secondary data and emission factors from ecoinvent v3.10 EN15804GD. As modelled herein, the module A1 through module A5 global warming potential for CoolSeal GuardTop's asphalt emulsion sealcoat product was determined to be 2.5858 kg $CO_2e/1\ m^2$, ozone depletion is 1.4714×10^{-7} kg CFC-11-eq /1 m^2, acidification is 0.01619 kg $SO_2e/1\ m^2$, eutrophication is 0.01530 kg N eq/1 m^2, tropospheric ozone (smog formation potential) is 0.18442 kg $O_3e/1\ m^2$, and depletion of non-renewable energy resources (PENRT) is 43.216 MJ/1 m^2.

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Appendix

Appendix A.1: Process Data for CoolSeal production

The process data for the CoolSeal asphalt sealant production process as provided by GuardTop CoolSeal is detailed below:

Material and Energy Inputs	***Quantity***	***Units***
Electricity (GuardTop Facility)	386,760	kWh/year
Diesel	118	gal/year
Titanium Dioxide	287,397	kg/year
Infrared Black Pigment	47,028	kg/year
Water	119,139	kg/year
Asphalt Emulsion	225,734	kg/year
Latex Polymer	182,887	kg/year
Calcium Carbonate	87,786	kg/year
Biocide	8,360	kg/year
SS-1h	261,269	kg/year
Aluminium Oxide	21,243	kg/year

Exhibit 34: Process Data for CoolSeal Production

Appendix A.2 Data Quality Assessment Methodology

The data sources were assessed in terms of their temporal, geographical, and technological correlation in this study. The matrix below demonstrates NETL's DQI methodology, which was being used as the basis for the scoring:

Indicator	***Score***				
	1	**2**	**3**	**4**	**5**
Temporal	less than three years of difference to year of study/current year	less than 6 years of difference	less than 10 years difference	less than 15 years difference	age of data unknown or more than 15 years difference
Geographical	data from area under study	average data from larger area or specific data from a close area	data from area with similar production conditions	data from area with slightly similar production conditions	data from unknown area or area with very different production conditions
Technological	data from technology, process or materials being studied	data from a different technology using the same process and/or materials		data on related process or material using the same technology	data or related process or material using a different technology

Exhibit 35: Data Quality Assessment Matrix