

# **LIFE CYCLE ASSESSMENT (LCA) OF RAINSCREEN CLADDING SUPPORT SYSTEMS**

## **Public version**

For Type III environmental declarations visit:  
<https://transparencycatalog.com/company/knight-wall-systems>

Status Public

Client Knight Wall Systems (KWS)



Date May 2025

Authors Tejan Adhikari, Sustainable Minds  
Kim Hammer, Sustainable Minds

## EXECUTIVE SUMMARY

KNIGHT WALL SYSTEMS® (KWS®) is a leading innovator in rainscreen cladding support systems, setting new industry standards with its proprietary “drop-in” rainscreen and thermal isolation technologies. Focused on designing energy-effective and environment-conscious rainscreen support solutions, KWS aims to shape the future of cladding support products by improving their environmental performance. To assess and enhance such performance, KWS commissioned Sustainable Minds to conduct a cradle-to-gate life cycle assessment (LCA) of its rainscreen cladding support systems.

Five rainscreen cladding support systems are evaluated in this study: CI® system, HCI system, PanelRail® & RevealRail, ThermaZee®, and MFI® system. All but the MFI system feature a bracketless design. While multiple configurations exist for each system, this analysis focuses on representative configurations selected based on product popularity and sales share. Additionally, impact scaling factors are developed to enable impact assessments across all available configurations. The declared unit for this study is 0.6096 meters (24 linear inches) of the cladding support system, consisting of a 24-inch length of metal rails and a single clip unit if applicable, with clips included only in the KWS MFI system. The LCA was conducted in accordance with the relevant PCR and ISO standards using a cradle-to-gate approach. This assessment covers the stages from raw material extraction through final assembly, including material transportation between supplier and manufacturing facilities, manufacturing operations, and the final product’s readiness for shipment at the manufacturing facility gate.

A high-level summary of the study’s findings is presented in the table below, which details the impacts per declared unit for the representative product in each system. The table includes potential CO<sub>2</sub>-equivalent emissions, fossil fuel depletion potential, eutrophication potential, and SM single score results for each rainscreen cladding support system type. For additional impact categories, refer to the full report. The raw material extraction and upstream production module (A1) is the primary contributor to cradle-to-gate impacts across all categories, largely due to the environmental burden of steel production and processing. Key impacts stem from raw material extraction, refinement, and the slitting of steel sheets and coils to the required dimensions. Collaboration with the supply chain, including material suppliers, slitters, and logistics providers, is recommended for refining sustainability strategy. Exploring alternative raw material sources, optimizing transportation efficiency, and working with low-emission logistics providers can help reduce impacts. Encouraging suppliers to adopt sustainable manufacturing practices or integrate renewable energy can further enhance environmental performance.

**Table i.** High-level results summary per declared unit of KWS products evaluated in this study

Rainscreen cladding support system	Impact category	Unit	Extraction & upstream production	Transport to factory	Manufacturing	Cradle-to-gate total
			A1	A2	A3	A1-A3
CI® system	Global warming	kg CO <sub>2</sub> eq	3.37E+00	1.90E-01	8.00E-02	<b>3.64E+00</b>
		%	92.5%	5.31%	2.15%	<b>100%</b>
	Fossil fuel depletion	MJ surplus	2.23E+00	3.70E-01	8.00E-02	<b>2.68E+00</b>
		%	83.2%	13.7%	3.14%	<b>100%</b>
	Eutrophication	kg N eq	8.89E-03	1.46E-03	4.23E-04	<b>1.08E-02</b>
		%	89.9%	6.53%	3.57%	<b>100%</b>
	SM single figure score	mPts	2.11E-01	1.03E-02	4.77E-03	<b>2.26E-01</b>
		%	93.3%	4.57%	2.11%	<b>100%</b>
HCI system	Global warming	kg CO <sub>2</sub> eq	4.56E+00	2.60E-01	9.00E-02	<b>4.92E+00</b>
		%	92.8%	5.33%	1.86%	<b>100%</b>
	Fossil fuel depletion	MJ surplus	3.02E+00	5.00E-01	1.00E-01	<b>3.61E+00</b>
		%	83.5%	13.8%	2.77%	<b>100%</b>
	Eutrophication	kg N eq	1.20E-02	1.97E-03	5.05E-04	<b>1.45E-02</b>
		%	90.2%	6.55%	3.22%	<b>100%</b>
	SM single figure score	mPts	2.86E-01	1.40E-02	5.80E-03	<b>3.06E-01</b>
		%	93.5%	4.58%	1.90%	<b>100%</b>
PanelRail® & RevealRail	Global warming	kg CO <sub>2</sub> eq	3.74E+00	2.10E-01	8.00E-02	<b>4.03E+00</b>
		%	92.7%	5.32%	2.01%	<b>100%</b>
	Fossil fuel depletion	MJ surplus	2.47E+00	4.10E-01	9.00E-02	<b>2.96E+00</b>
		%	83.3%	13.7%	3.02%	<b>100%</b>
	Eutrophication	kg N eq	9.85E-03	1.62E-03	4.37E-04	<b>1.19E-02</b>
		%	90.2%	6.55%	3.29%	<b>100%</b>
	SM single figure score	mPts	2.34E-01	1.14E-02	4.89E-03	<b>2.50E-01</b>
		%	93.5%	4.57%	1.95%	<b>100%</b>
ThermaZee®	Global warming	kg CO <sub>2</sub> eq	5.11E+00	2.80E-01	9.00E-02	<b>5.48E+00</b>
		%	93.3%	5.10%	1.60%	<b>100%</b>
	Fossil fuel depletion	MJ surplus	4.25E+00	5.30E-01	1.00E-01	<b>4.88E+00</b>
		%	87.0%	10.9%	2.10%	<b>100%</b>
	Eutrophication	kg N eq	1.37E-02	2.02E-03	4.66E-04	<b>1.62E-02</b>
		%	91.3%	6.16%	2.53%	<b>100%</b>
	SM single figure score	mPts	3.15E-01	1.50E-02	5.10E-03	<b>3.35E-01</b>
		%	94.0%	4.48%	1.52%	<b>100%</b>
MFI® system	Global warming	kg CO <sub>2</sub> eq	3.71E+00	2.10E-01	8.00E-02	<b>4.00E+00</b>
		%	92.8%	5.16%	2.06%	<b>100%</b>
	Fossil fuel depletion	MJ surplus	2.65E+00	3.90E-01	1.20E-01	<b>3.16E+00</b>
		%	83.8%	12.4%	3.80%	<b>100%</b>
	Eutrophication	kg N eq	1.40E-03	9.85E-05	4.71E-05	<b>1.54E-03</b>
		%	90.6%	6.39%	3.05%	<b>100%</b>
	SM single figure score	mPts	2.35E-01	1.10E-02	4.77E-03	<b>2.51E-01</b>
		%	93.7%	4.40%	1.90%	<b>100%</b>

## CONTENTS

<b>1</b>	<b>INTRODUCTION.....</b>	<b>1</b>
1.1.	OPPORTUNITY .....	1
1.2.	LIFE CYCLE ASSESSMENT (LCA) .....	1
1.3.	TEAM .....	3
1.4.	STATUS .....	3
<b>2</b>	<b>GOAL AND SCOPE.....</b>	<b>4</b>
2.1.	INTENDED APPLICATION AND AUDIENCE.....	4
2.2.	PRODUCT DESCRIPTION .....	4
2.3.	DECLARED UNIT .....	8
2.4.	SYSTEM BOUNDARY .....	9
2.4.1	<i>Production stage (A1-A3)</i> .....	9
<b>3</b>	<b>LIFE CYCLE INVENTORY ANALYSIS.....</b>	<b>11</b>
3.1.	DATA COLLECTION PROCEDURES .....	11
3.2.	PRIMARY DATA .....	11
3.2.1.	<i>Extraction, upstream production, and transport to factory (A1-A2)</i> .....	11
3.2.2.	<i>Manufacturing (A3)</i> .....	12
3.2.3.	<i>Additional information for biogenic carbon disclosure</i> .....	14
3.3.	BACKGROUND DATA .....	15
3.3.1.	<i>Materials</i> .....	15
3.3.2.	<i>Transportation</i> .....	16
3.3.3.	<i>Energy and upstream processing</i> .....	16
3.3.4.	<i>Disposal</i> .....	16
3.4.	CUT-OFF CRITERIA .....	17
3.5.	ALLOCATION .....	17
3.6.	DISCUSSION OF DATA QUALITY .....	18
3.7.	COMPARABILITY.....	19
3.8.	ASSUMPTIONS AND LIMITATIONS .....	19
<b>4</b>	<b>IMPACT ASSESSMENT METHODS.....</b>	<b>21</b>
4.1.	IMPACT ASSESSMENT CHARACTERIZATION .....	21
4.2.	NORMALIZATION AND WEIGHTING .....	22
<b>5</b>	<b>ASSESSMENT AND INTERPRETATION.....</b>	<b>23</b>
5.1.	DATA QUALITY ASSESSMENT .....	23
5.2.	RESOURCE USE AND WASTE FLOWS.....	23
5.2.1.	<i>Cl<sup>o</sup> system</i> .....	25
5.2.2.	<i>HCl system</i> .....	26
5.2.3.	<i>ThermaZee<sup>o</sup></i> .....	27
5.2.4.	<i>PanelRail<sup>o</sup> &amp; RevealRail</i> .....	28
5.2.5.	<i>MFI<sup>o</sup> system</i> .....	29
5.3.	LIFE CYCLE IMPACT ASSESSMENT (LCIA) .....	30
5.3.1.	<i>Cl<sup>o</sup> system</i> .....	30
5.3.2.	<i>HCl system</i> .....	33
5.3.3.	<i>ThermaZee<sup>o</sup></i> .....	35
5.3.4.	<i>PanelRail<sup>o</sup> &amp; RevealRail</i> .....	38
5.3.5.	<i>MFI<sup>o</sup> system</i> .....	40
5.3.6.	<i>MFI<sup>o</sup> system – single bracket only</i> .....	43
5.3.7.	<i>MFI<sup>o</sup> system – rail only</i> .....	43
5.4.	SENSITIVITY ANALYSIS.....	44
5.5.	OVERVIEW OF RELEVANT FINDINGS.....	45
5.6.	CONCLUSION AND RECOMMENDATIONS .....	46
<b>6</b>	<b>REFERENCES.....</b>	<b>47</b>

# 1 INTRODUCTION

## 1.1. Opportunity

Knight Wall Systems (KWS) is a leading innovator in rainscreen cladding support systems, setting new industry standards with its proprietary “drop-in” rainscreen and thermal isolation technologies. Designed for both new construction and renovation projects, KWS’s advanced rainscreen solutions provide superior structural performance, thermal efficiency, and design flexibility. Engineered to accommodate nearly any cladding or building type, KWS systems ensure seamless integration while enhancing building envelope performance. With a focus on designing energy-effective and environment-conscious rainscreen support solutions, KWS aims to shape the future of cladding support products by improving their environmental performance while remaining committed to sustainable manufacturing practices. These high-quality and high-performance solutions reflect KWS’s dedication to innovation, precision, and reliability.

As part of its ongoing commitment to environmental sustainability, KWS has embarked on a project to develop environmental product declarations (EPDs) for its rainscreen cladding support systems. The first step is to transparently communicate the potential environmental impacts and performance of the products. As a result, it is important to conduct a life cycle assessment (LCA) to evaluate the potential environmental impacts from raw materials acquisition through manufacturing. The goal is to explore the potential environmental impacts that rainscreen cladding support systems have and to identify ways to improve processes and reduce impacts.

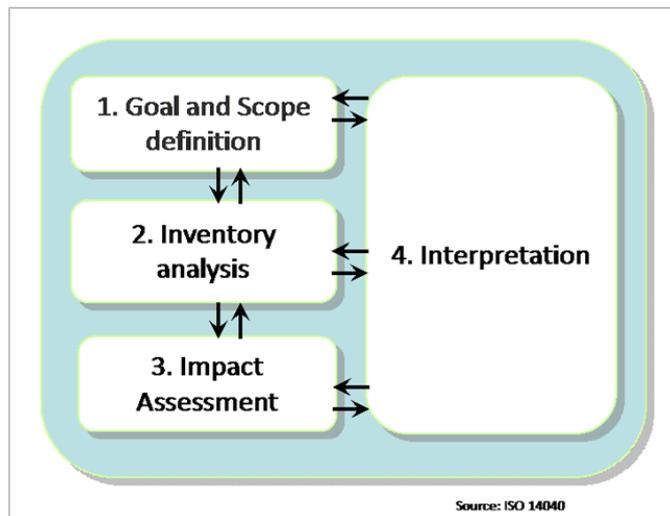
To understand the true potential environmental impacts, KWS commissioned Sustainable Minds to help develop an LCA for its rainscreen cladding support systems using a cradle-to-gate approach. KWS is looking forward to having guidance for future product improvements that can be informed by the results of this study.

KWS is interested in having LCA data available for its rainscreen cladding support systems to be able to obtain Sustainable Minds Transparency Reports [EPDs]<sup>™</sup> (TRs), which are ISO 14025 Type III [1] environmental declarations that can be used for communication with and amongst other companies, architects, and consumers, and that can also be utilized in whole building LCA tools in conjunction with the LCA background report and life cycle inventory (LCI). This study conforms to the requirements of ISO 14040/14044 [2], ISO 21930:2017 [3], Sustainable Minds Part A: LCA calculation rules and report requirements [4], and Sustainable Minds Part B for cladding support components and systems [5].

## 1.2. Life cycle assessment (LCA)

LCA is performed to comprehensively explore, quantify, and interpret the potential environmental impacts associated with a product or service over the entire life cycle. A product’s life cycle consists of various stages, starting from raw material acquisition and manufacturing to product use and maintenance, plus final product disposal. Depending on the inclusion or exclusion of life cycle stages, an LCA could be cradle-to-gate (from raw material acquisition to the manufactured product ready to be shipped), cradle-to-gate with options (which also optionally includes other modules such as shipment and installation), or cradle-to-grave (which includes all other stages including the use phase and disposal once the useful life is over).

Any LCA conducted with the intention of publishing EPDs needs to comply with the internationally accepted ISO 14040 and ISO 14044 standards. ISO 14040 provides principles and frameworks for conducting an LCA, while ISO14044 specifies requirements and provides guidelines for an LCA. ISO 14040 sets out a four-phase methodology framework for completing a LCA, as depicted in Figure 1.



**Figure 1.** Phases of an LCA

- **Goal and scope definition:** Goals refer to establishing the purpose of the LCA, and they define the environmental aspects to be studied and the intended audience. Scope outlines the system boundaries, the functional unit of analysis, and the life cycle stages to be included. System boundaries set up inclusions and exclusions in an LCA. PCRs usually specify whether the boundary must be cradle-to-gate, cradle-to-installation, or cradle-to-grave.
- **Life cycle inventory analysis:** In this step, a detailed inventory of all the environmental inputs and outputs associated with each stage of the product's life cycle is compiled. Primary data about materials, energy, and emissions assessing the upstream supply chain, company's manufacturing operations, and downstream processes (after product leaves the factory gate) are collected via LCI data collection templates or tools. Annual data is suggested in most cases to be representative of the manufacturing operations. In the case of multi outputs, resources can be allocated to the product of interest via mass or volume, or as relevant. The inventory is then scaled to meet the functional unit of the LCA.
- **Life cycle impact assessment:** The compiled LCI is then modeled using an LCA software like SimaPro, GaBi, openLCA, or others using suitable background data sets available on their databases. Each is assigned to categories according to different impact methodologies, and the software provides final impact values for those different environmental impact categories. Several LCIA methodologies exist in the market including ReCiPe, TRACI, CML, and ILCD, which differ in terms of their approaches, characterization factors, evaluated impact categories, and modeling assumptions. Practitioners can choose a combination of LCIA methodologies to provide a holistic view of the environmental performance of a product.
- **Interpretation of results:** In this step, the LCIA results are analyzed and presented via an LCA report. This stage helps draw conclusions about the

environmental performance of the product, identify any environmental hotspots, make recommendations, and assess the significance of the findings. Sensitivity analysis, scenario studies, and uncertainty assessment are often included as a part of the interpretation to ensure the reliability and robustness of the results. LCA, if well interpreted and evaluated, presents a number of opportunities for the manufacturer in developing sustainability goals and initiatives.

This LCA study follows an attributional approach and uses a cradle-to-gate system boundary. This report incorporates LCA terminology. To assist the readers in understanding LCA, special attention has been given to list definitions of important terms used at the end of this report.

A critical review of the LCA and an independent verification of the TR are required for ISO 14025 Type III environmental declarations. Both are included in this project.

### **1.3. Team**

This LCA report is the outcome of efforts from the project team led by the Zac Turcott, Engineering Specialist at KWS, with support from other KWS personnel during the data collection, reporting, and interpretation phases. Sustainable Minds led the development of the LCA results, LCA report, and Transparency Reports [EPDs]™.

### **1.4. Status**

All information in this report reflects the best possible data inventory by KWS at the time it was collected, and Sustainable Minds and KWS adhered to best practices in transforming the inventory into this report.

Primary data was provided for annual manufacturing and supply chain data for January 2024 – December 2024 from KWS's manufacturing facility in Deer Park, WA. Where data was missing, assumptions were made for the facilities based on expertise from KWS. This study also includes background data to complete the inventory and fill gaps where necessary.

This is a supporting LCA report for the KWS Transparency Reports [EPDs]™ and was evaluated for conformance to the PCRs according to the ISO 14025 and ISO 14040/14044 standards. The LCA review and verification of the Sustainable Minds Transparency Reports [EPDs]™ were carried out by Thomas P. Gloria, Ph.D., Industry Ecology Consultants to determine conformance to ISO 14040/14044 and the relevant PCRs.

## 2 GOAL AND SCOPE

This chapter explains the goal and scope of the study. The aim of the goal and scope is to define the product under study and the depth and breadth of the analysis.

### 2.1. Intended application and audience

This report intends to define the specific application of the LCA methodology to the life cycle of the rainscreen cladding support systems manufactured by KWS. The report serves both internal and external purposes and is intended for a diverse audience. The intended audience includes the program operator (Sustainable Minds) and reviewer who will be assessing the LCA for conformance to the PCR, as well as KWS's internal stakeholders involved in marketing and communications, operations, and design.

The results presented in this document are not meant to support comparative claims. The outcomes will be made available to the public in Sustainable Minds Transparency Reports [EPDs]™ (Type III environmental declarations per ISO 14025), which are intended for communication between businesses and consumers (B2C).

### 2.2. Product description

A rainscreen is an exterior cladding system designed to enhance a building's durability and energy efficiency. It is installed away from the building's water-resistant barrier, creating a ventilated air cavity behind the cladding. This cavity, vented at both the top and bottom, allows moisture that penetrates the cladding to drain away while promoting rapid evaporation through passive airflow. Additionally, rainscreens improve energy efficiency by accommodating exterior insulation, reducing thermal bridging, and enhancing overall building performance.

Knight Wall Systems' thermally isolated rainscreen cladding support systems offer a unique approach to enhancing building performance. These systems not only create an air cavity to minimize water contact with the primary building envelope but also provide a highly efficient support structure for attaching nearly any type of cladding. Designed to accommodate true continuous insulation, they significantly improve energy efficiency while protecting the building's vital and delicate envelope. With unparalleled design flexibility, these rainscreen systems support a wide range of cladding options, including ACM, fiber cement, UHPC, modern composites, adhered stone veneer, stucco, and more. Listed below are the benefits of using KWS rainscreen cladding support systems:

- Supports proper moisture management by enabling bulk water drainage away from the water resistive barrier
- Allows water vapor behind cladding and insulation to escape through evaporation
- Reduces energy costs by minimizing thermal bridging
- Enables the use of exterior insulation to help meet energy code requirements
- May be used to create an air space behind the cladding that enhances drainage, ventilation, and drying
- Offers design flexibility with seamless transitions between various cladding materials

Five different rainscreen cladding support system types have been evaluated in this study: CI® system, HCI system, PanelRail® & RevealRail, ThermaZee®, and MFI® system. All but the MFI system are bracketless systems.

The CI system uses unique  $\frac{3}{4}$ " deep vertical box girts, called CI-GIRT®, and the HCI system uses unique  $\frac{3}{4}$ " deep horizontal girts, called HCI-GIRT, both designed to properly disburse the façade loads over exterior rigid insulation. Both CI and HCI system components are available in standard and custom lengths, in either 16- or 18-gauge options. For this study, an 18-gauge CI-GIRT with a 0.75" depth configuration was selected as the representative product for CI system, while an 18-gauge HCI-GIRT with a 0.75" depth configuration was chosen as the representative product for HCI system. These selections were based on product popularity and sales share.

ThermaZee employs a specially designed, webbed, polymer thermal isolation strip, complementing numerous performance enhancements in the steel girt. It can be installed either vertically or horizontally and is available in either 16- or 18-gauge options with varying depths and lengths. An 18-gauge ThermaZee with a 4" depth was selected as the representative product for this study.

PanelRail & RevealRail are typically used as a second layer of rails atop the CI, HCI, and MFI systems or other types of assemblies to help accommodate different panel layouts, sizes, or depths. These are also available in either 16- or 18-gauge options with varying depths and lengths. The representative product for this study was selected to be an 18-gauge configuration, featuring a 2" face and a 0.75" depth.

The MFI system is an innovative clip and rail system designed for superior thermal efficiency and design flexibility when used in conjunction with mineral fiber or spray foam insulation. It features a continuous rail mounted to intermittent, thermally isolated clips known as ThermaBracket®, which can be installed in either a vertical or horizontal orientation. Integrated with the ThermaStop™ thermal isolation assembly, this system minimizes thermal bridging and enhances energy performance. There are two versions available: the S-Series and the D-Series. The S-Series MFI system is static, with a fixed S-Rail to ThermaBracket connection, while the D-Series MFI system is dynamic, featuring an adjustable D-Rail to ThermaBracket connection. Both versions are offered in 16- or 18-gauge options, with varying depths and lengths to accommodate different project requirements. The representative product system for this study was selected to be a 16-gauge S-series rail and 2" depth S-series bracket.

Figure 2 provides representative product images for the KWS rainscreen cladding support systems evaluated in this study. Table 1 lists the product information in accordance with PCR, including the declaration name, products included in the declaration, CSI MasterFormat® classification, manufacturing location, and the type of declaration. Table 2 lists the product properties as prescribed by the PCR.

<p>CI® system</p>	
<p>HCI system</p>	
<p>ThermaZee®</p>	
<p>PanelRail® &amp; RevealRail</p>	
<p>MFI® system</p>	

**Figure 2.** Visual representation of evaluated products

**Table 1.** Declared product information and type of declaration

Transparency Report [EPD]™ name	Product option	CSI MasterFormat® classification	Manufacturing location	Type of declaration
CI® and HCI system	CI® system	07 05 43 07 48 00	Deer Park, WA	Product-specific, plant-specific declaration for one manufacturer
	HCI® system			
ThermaZee®				Product-specific, plant-specific declaration for one manufacturer
PanelRail® & RevealRail				Product-specific, plant-specific declaration for one manufacturer
KWS™ MFI® System				Product-specific, plant-specific declaration for one manufacturer

**Table 2.** Product properties

Properties	CI® system	HCI® system	ThermaZee®	PanelRail® & RevealRail™	MFI® System	Unit
Cladding support type	Continuous girt			Metal rail	Clip and metal rail	-
Exterior cavity depth (from sheathing to face of the girt)*	69.85 (2.75)	69.85 (2.75)	101.6 (4)	19.05 (0.75)	69.85 (2.75)	mm (inch)
Mass per declared unit	0.708	0.912	0.708	0.762	0.742	kg
Number of clips per declared unit	-	-	-	-	1	piece
Length of rails, hat channels, and/or girts per declared unit	0.610 (24.0)					m (inch)
*Depth of exterior wall assembly can vary based on each product used and the unique requirements of each project. The listed depths are used for representative purposes only.						

Table 3 summarizes the applicable product specifications for each product.

**Table 3.** Other product information

Product name	Product specifications
CI <sup>®</sup> system	<ul style="list-style-type: none"> <li>• Non-combustible girt and rails</li> <li>• Vertical CI-GIRT<sup>®</sup> can be typically spaced 16", 24" or 32" O.C. depending on imposed loads</li> <li>• Support cladding weighing up to 20 PSF</li> <li>• Highly corrosion resistant Zn-Al-Mg ZM40 (ASTM A1046) coated steel provides 10x the protection vs typical G90 galvanized steel</li> <li>• Black PVDF finish or stainless steel options available</li> <li>• Easily installed over any type of substrate – steel studs, wood studs, CMU, concrete</li> </ul>
HCI system	<ul style="list-style-type: none"> <li>• Non-combustible girt and rails</li> <li>• Horizontal HCI-GIRT can be typically spaced from 12" up to 48" O.C. depending on imposed loads</li> <li>• Support cladding weighing up to 20 PSF</li> <li>• Highly corrosion resistant Zn-Al-Mg ZM40 (ASTM A1046) coated steel provides 10x the protection vs typical G90 galvanized steel</li> <li>• Black PVDF finish or stainless steel options available</li> <li>• Easily installed over any type of substrate – steel studs, wood studs, CMU, concrete</li> </ul>
ThermaZee <sup>®</sup>	<ul style="list-style-type: none"> <li>• Non-combustible girt for a reliable structural connection</li> <li>• Highly perforated for increased drainage</li> <li>• Can be typically spaced up to 48" O.C. when used horizontally, or up to a 32" O.C. when used vertically depending on imposed loads</li> <li>• Pre-punched wall anchor holes for easy installation, especially over wood and CMU/concrete substrates</li> <li>• Highly corrosion resistant Zn-Al-Mg ZM40 (ASTM A1046) coated steel provides 10x the protection vs typical G90 galvanized steel</li> <li>• Black PVDF finish or stainless steel options available</li> <li>• Easily installed over any type of substrate – steel studs, wood studs, CMU, concrete</li> </ul>
PanelRail <sup>®</sup> & RevealRail	<ul style="list-style-type: none"> <li>• Depth: 0.75", 1.00", 1.25", 1.50", 1.75", or custom</li> <li>• Rail width: 2", 3", 4", 5", or custom</li> <li>• Material: ASTM A1046 steel, ZM40, 50 ksi yield</li> <li>• Gauge: 18-ga (46 mil) or 16-ga (55 mil)</li> <li>• Finish: Mill or PVDF black</li> <li>• All rails are perforated for drainage and ventilation</li> </ul>
MFI <sup>®</sup> system	<ul style="list-style-type: none"> <li>• Non-combustible clip &amp; rails for a reliable structural connection</li> <li>• ThermaBracket<sup>®</sup> can be typically spaced up to 48" O.C. vertically, and 16", 24", or 32" O.C. horizontally depending on imposed loads</li> <li>• Support cladding weighing up to 20 PSF</li> <li>• Highly corrosion resistant Zn-Al-Mg ZM40 (ASTM A1046) coated steel provides 10x the protection vs typical G90 galvanized steel</li> <li>• Black PVDF finish or stainless steel options available</li> <li>• Easily installed over any type of substrate – steel studs, wood studs, CMU, concrete</li> </ul>

For more information about the products, including details about the materials that conform to the relevant standards, visit <https://knightwallsystems.com/products/>.

### 2.3. Declared unit

This LCA covers the cradle-to-gate stage for rainscreen cladding support systems manufactured by KWS. According to the PCR, the declared unit is 0.6096 m (24 linear inches) of cladding support system consisting of a single clip unit, if applicable, and 24 inches length of metal rails with the clip spaced at one per 24 inches.

A clip is only present in the MFI<sup>®</sup> system. The exterior cavity depth is sufficient to accommodate 101.6 mm (4 inches) of insulation plus depth of support components outboard of the insulation layer to which the cladding is attached. Fasteners are excluded.

## 2.4. System boundary

This section describes the system boundary for the analysis. The system boundary defines which life cycle stages are included and which are excluded.

This LCA's system boundary is from cradle to gate. Therefore, the life cycle activities and related processes shall include life cycle stage modules only from A1-A3 as illustrated in Figure 3. This covers raw material extraction and preprocessing, transportation to the manufacturing facility, and product manufacturing. The system boundary ends at the manufacturing facility's gate, with the products ready for shipment to end users. Table 4 lists specific inclusions and exclusions for the system boundary.

Scope	PRODUCTION STAGE			CONSTRUCTION STAGE		USE STAGE					END-OF-LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	D
	Extraction and upstream production	Transport to factory	Manufacturing	Transport to site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Deconstruction/Demolition	Transport to waste processing or disposal	Waste processing	Disposal of waste	Reuse, Recovery, Recycling Potential
						B6 Operational energy use									
						B7 Operational water use									
<b>Cradle to gate</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>MND</b>	<b>MND</b>	<b>MND</b>	<b>MND</b>	<b>MND</b>	<b>MND</b>	<b>MND</b>	<b>MND</b>	<b>MND</b>	<b>MND</b>	<b>MND</b>	<b>MND</b>

**Figure 3.** Applied system boundary

**Table 4.** System boundary inclusions and exclusions

Included	Excluded
<ul style="list-style-type: none"> <li>Raw material extraction for components</li> <li>Transport of raw materials/components to the final product manufacturing facility</li> <li>Processing of raw materials into components</li> <li>Other inputs to the factory and internal transport</li> <li>Energy production</li> <li>Manufacturing scrap and its disposal</li> <li>Packaging for the final product (material extraction, upstream processing, and its transport to the manufacturing facility)</li> </ul>	<ul style="list-style-type: none"> <li>Construction of major capital equipment</li> <li>Manufacture of support equipment</li> <li>Human labor and employee transport</li> <li>Manufacture and transport of packaging materials not associated with final product</li> <li>Building operational energy and water use</li> <li>Installation at building site</li> <li>Disposal of final product packaging</li> </ul>

### 2.4.1 Production stage (A1-A3)

The production stage starts when raw materials are extracted from nature and ends when the product is packaged and ready to be loaded onto a transport vehicle at the KWS facility.

The production stage includes three product life cycle modules:

- I. **Extraction and upstream preprocessing (A1)**
  - Extraction and processing of raw materials
  - Transport of raw materials from extraction/production to manufacturer
  - Energy and water consumption for raw material manufacturing

- II. **Transport to factory (A2)**
  - Transportation of components to the KWS manufacturing facility
- III. **Manufacturing (A3)**
  - Energy and water consumption for product manufacturing
  - Product packaging inputs
  - Releases to environmental media (air, soil, ground, & surface water)
  - Manufacturing waste transportation from plant to disposal sites
  - Manufacturing waste disposal/recycling/reuse/energy recovery
  - Final product preparation for outbound shipment

# 3

## LIFE CYCLE INVENTORY ANALYSIS

This chapter includes an overview of the obtained data and data quality that has been used in this study. A complete life cycle inventory calculation workbook, which catalogs the flows crossing the system boundary and provides the starting point for life cycle impact assessment, can be found in the appendix.

### 3.1. Data collection procedures

Data used for this study represents a mix of primary data collected from KWS on the manufacturing process and background data from LCI databases. Upstream processing assumptions were developed using suggestions made by KWS based on their discussions with the upstream suppliers, and primary data was obtained when possible. Overall, the quality of the data used in this study is considered to be good and representative of the described systems. All appropriate means were employed to guarantee the data quality and representativeness as described.

Primary data was provided by KWS representing the supply chain (A1-A2) and manufacturing operations (A3). Data was collected in a consistent manner and level of detail to ensure high-quality data. All submitted data was checked for quality multiple times on the plausibility of inputs and outputs using mass balance and benchmarking. All questions regarding data including gaps, outliers, and any inconsistencies were resolved with KWS and their suppliers. Annual data representing both the supply chain and manufacturing operations were collected for the manufacturing facility in Deer Park, WA. Annual data was collected for 2024 (January 2024 through December 2024) to provide a more comprehensive representation of the operations and supply chain. The resulting inventory calculations were developed by an analyst at Sustainable Minds and subsequently checked internally.

The model was developed in SimaPro with consistency in mind. Expert judgment was used in selecting appropriate data sets to model the materials, material processing, and energy for this study and has been noted in the following sections. Databases adopted in the model include ecoinvent v3.10, Industry data 2.0, and US-EI 2.2 databases.

### 3.2. Primary data

Primary data was collected from KWS to represent their annual operations and supply chain. This data was gathered through direct measurements or, when measurements were unavailable, based on engineering estimates provided by manufacturing facility personnel, reflecting actual production. While annual data was collected for all processes within KWS's control, assumptions were made to represent upstream component processing. These assumptions were informed by discussions with upstream suppliers about their facility operations and the components they supply to KWS.

#### 3.2.1. Extraction, upstream production, and transport to factory (A1-A2)

These modules represent raw materials extraction, preprocessing/upstream production, and shipment to the manufacturing facility.

KWS provided detailed material composition data for all rainscreen cladding support systems. These product systems do not contain hazardous substances according to the standards or regulations of the Resource Conservation and Recovery Act (RCRA), Subtitle C.

Primary supply chain data was also provided, including supplier locations, shipping distances, and transport modes to the final manufacturing plant. Girts and rails follow the same transportation route. Steel coils are first shipped by rail from steel mills, where the coils are slit to the required widths and cut to the appropriate lengths. Metal slitting reported an average scrap rate of 1.29%, with the scrap steel being recycled.

Final product packaging, including upstream transport, is included in the manufacturing (A3) module per ISO 21930.

Due to the availability of several variations within each of the five rainscreen system types, one representative configuration was selected for each system type. Material composition and transportation data for KWS rainscreen cladding support systems are reported in Table 5 and Table 6, respectively.

**Table 5.** Raw material composition and packaging inputs per declared unit

*Submitted to the verifier*

**Table 6.** Raw material supplier transportation modes and distances by material

*Submitted to the verifier*

### **3.2.2. Manufacturing (A3)**

All KWS™ Rainscreen Wall Systems and KWS MFI System products evaluated in this study are manufactured at the KWS plant in Deer Park, WA.

Steel coils used as a raw material for girts and rails first are slit down to final dimensions before being punched and formed are further processed.

The CI® system, HCl® system, and PanelRail® and RevealRail are produced using either steel coils or sheets and formed into typically 8ft or 10ft girts. The formed girts and rails are then stacked in wooden crates for storage or immediate shipment to customers. This process ensures consistent quality and efficiency, allowing for reliable supply and quick fulfillment of orders.

ThermaZee® is punched, flared, and formed before a polymer isolator is attached to each piece. Finished girts are then stacked in wooden crates for storage or shipment.

For the KWS MFI System, MFI rails follow the same manufacturing pattern as the other rainscreen wall systems products. The finished rails, typically 8ft or 10ft long, are stacked in wooden crates for storage or shipment. MFI brackets are punched into shape and then assembled, attaching injection-molded polypropylene isolators to the base and head. Assembled brackets are packed in plastic corrugated boxes for storage or shipment, with each box holding an average of 60 lbs. The final MFI rails and MFI brackets are then shipped together as the MFI system.

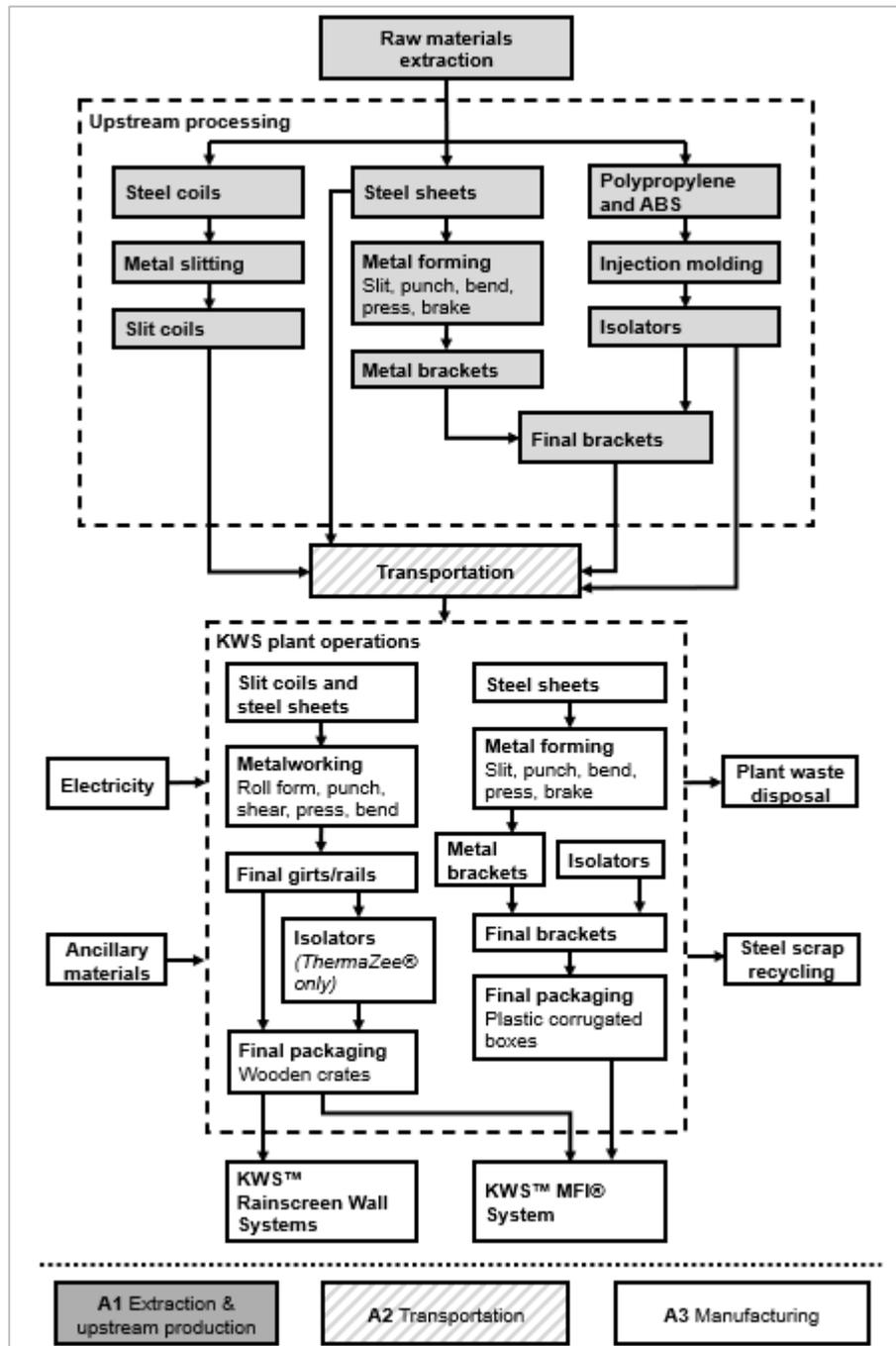
All rainscreen wall systems are packaged in wooden crates, each typically holding 4,000 lbs of product. Steel banding is used to secure the crates. KWS reported that each wooden crate weighs 350 lb, with approximately 43% of the mass coming from kiln-dried wood and 57% from plywood.

KWS provided manufacturing data covering the year 2024. The generation of steel scrap during KWS processing varied between system types. KWS provided primary data on steel scrap separately for each system type, and all scrap was sent to recycling centers. Plastic sheeting and miscellaneous waste, however, were assumed to be evenly distributed across all system types and sent to incineration centers for energy recovery. Waste transport distances were also provided. Resource inputs (energy and ancillary materials) and outputs (waste streams) during manufacturing are listed in Table 7. **Error! Reference source not found.**

**Table 7.** Manufacturing inputs and waste per declared unit

Resource category	Flow	Unit	CI <sup>®</sup> system	HCI <sup>®</sup> system	PanelRail <sup>®</sup> & RevealRail <sup>™</sup>	ThermaZee <sup>®</sup>	MFI <sup>®</sup> system
<b>Energy</b>	Electricity	kWh	█				█
<b>Ancillary materials</b>	Non-chlorinated cleaner	lb	█				
	Lubricants	lb	█				
<b>Waste generation</b>	Incinerated plastic waste	lb	█				
	Incinerated miscellaneous waste	lb	█				
	Recycled steel scrap	lb	█	█	█	█	█
<b>Waste transport</b>	Transport for incineration	miles	27				
	Transport for recycling	miles	17				

Figure 4. **Error! Reference source not found.** provides an overview of the process flow during the life cycle of the studied products. This study has included all upstream energy and material flows related to production.



**Figure 4.** System boundary and product flow diagram of rainscreen cladding support system products

### 3.2.3. Additional information for biogenic carbon disclosure

This section discloses the biogenic carbon emissions associated with the final disposal of product packaging during installation (A5). While the impacts from installation are out of the scope of this cradle-to-gate study, ISO 21930:2017 requires that biogenic carbon emissions associated with packaging disposed after product installation are separately reported.

Product packaging consists of wood-based materials, so there are biogenic carbon removals associated with packaging in the manufacturing stage (A3). The biogenic carbon removals from this packaging are later accounted for as biogenic carbon

emissions from the packaging disposal in the installation stage (A5). The biogenic carbon emissions from packaging are detailed in Table 8.

**Table 8.** Biogenic carbon disclosure for rainscreen cladding support systems per declared unit

Product	Unit	Biogenic carbon emissions from packaging in A5
CI® system	kg CO <sub>2</sub>	1.13E-01
HCI® system	kg CO <sub>2</sub>	1.46E-01
PanelRail® & RevealRail™	kg CO <sub>2</sub>	1.13E-01
ThermaZee®	kg CO <sub>2</sub>	1.09E-01
MFI® system	kg CO <sub>2</sub>	9.28E-02

### 3.3. Background data

This section details the background data sets used for modeling all relevant activities associated with the cradle-to-gate life cycle of KWS rainscreen cladding support systems. Each table includes the data set name, database, reference year, and geographic region. The LCA model was developed using SimaPro Developer 9.6. Life cycle inventory data for the raw materials and processes involved in modeling the products were sourced from the ecoinvent v3.10, US-EI 2.2, and Industry Data 2.0 databases.

#### 3.3.1. Materials

Suitable data sets for each raw material were identified in the background databases, so no proxies were required. In cases where country-specific data were unavailable, global or rest-of-world averages were used to represent production in those regions. Table 9 lists the most relevant LCI data sets used in modeling the raw materials.

**Table 9.** Key material data sets used in inventory analysis

Raw material	Data set	Database	Technology	Reference year	Geography*
Steel coils	Steel cold rolled coil {GLO}   blast furnace route and electric arc furnace route   production mix, at plant   1kg, typical thickness between 0.15 - 3 mm. typical width between 600 - 2100 mm   LCI result	Industry data 2.0	Appropriate technology	2021	Global
Steel sheets	Steel hot dip galvanised {GLO}   blast furnace route and electric arc furnace route   production mix, at plant   1kg, typical thickness between 0.3 - 3 mm. typical width between 600 - 2100 mm   LCI result	Industry data 2.0	Appropriate technology	2021	Global
ABS	Acrylonitrile-butadiene-styrene copolymer {GLO}   market for acrylonitrile-butadiene-styrene copolymer   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Global
Polypropylene	Polypropylene, granulate {GLO}   market for polypropylene, granulate   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Global
Kiln dried fir	Sawnwood, beam, softwood, raw, dried (u=20%) {RoW}   market for sawnwood, beam, softwood, raw, dried (u=20%)   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Rest of World
Plywood	Plywood {RoW}   market for plywood   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Rest of World
Steel banding	Steel, unalloyed {GLO}   market for steel, unalloyed   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Global
Non-chlorinated cleaner	Tetrachloroethylene {RoW}   market for tetrachloroethylene   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Rest of World
Lubricating oil	Lubricating oil {RoW}   market for lubricating oil   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Rest of World

\* Rest of World represents non-Europe geography

### 3.3.2. Transportation

Raw materials and components are transported to the KWS manufacturing facility using various transport modes, including rail and road transport. Transportation data sets account for load factors, which represent an average of empty and fully loaded conditions, including empty backhauls. Data sets for each transportation mode were sourced from the available databases. US-specific transportation data were used when available; otherwise, generic global data sets were applied. Table 10 shows the most relevant LCI data sets used in modeling transportation.

**Table 10.** Transportation data sets used in inventory analysis

Transport mode	Data set	Database	Technology	Reference year	Geography
Freight truck	Transport, freight, lorry 16-32 metric ton, EURO6 {RoW}  market for transport, freight, lorry 16-32 metric ton, EURO6   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Rest of World
Rail transport	Transport, freight train {US}  market for transport, freight train   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	US
Waste transport	Municipal waste collection service by 21 metric ton lorry {GLO}  market for municipal waste collection service by 21 metric ton lorry   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Global

### 3.3.3. Energy and upstream processing

As the KWS facility is in Deer Park, WA, the most recent eGRID data set for the NWPP (Northwest Power Pool) subregion was used. Relevant processing data sets from ecoinvent v3.10 were selected to represent the upstream processing of purchased components. Table 11 shows the most relevant LCI data sets used in modeling energy and upstream processing.

**Table 11.** Key energy and upstream data sets used in inventory analysis

Energy source	Data set	Database	Technology	Reference year	Geography
KWS facility electricity	Electricity mix, eGrid subregion, NWPP/US U	US-EI 2.2 + EPA	Appropriate technology	2023	US
<b>Data sets for upstream processing</b>					
Metal processing	Metal working, average for steel product manufacturing {RoW}  metal working, average for steel product manufacturing   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Rest of World
Injection molding	Injection moulding {RoW}  injection moulding   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Rest of World

### 3.3.4. Disposal

Processes specific to waste types were selected to correspond to the disposal of facility waste streams. Table 12 lists the relevant disposal data sets used in the model.

**Table 12.** Key disposal data sets used in inventory analysis

Material disposed	Data set	Database	Technology	Reference year	Geography
Incinerated plastic waste	Waste polyethylene {GLO}  treatment of waste polyethylene, municipal incineration   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Global
Incinerated miscellaneous waste	Municipal solid waste {RoW}  treatment of municipal solid waste, municipal incineration   Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Rest of World

### 3.4. Cut-off criteria

The cut-off criteria on a unit process level can be summarized as follows:

- All inputs and outputs to a (unit) process shall be included in the calculation of the pre-set parameters results, for which data are available. Data gaps shall be filled by conservative assumptions with average, generic or proxy data. Any assumptions for such choices shall be documented. Assumptions and proxies, whenever used, have been explained in this report.
- Mass – If a flow is less than 1% of the cumulative mass of the model it may be excluded, providing its environmental relevance is not a concern. No known mass flow has been omitted in this study.
- Energy – If a flow is less than 1% of the cumulative energy of the model it may be excluded, providing its environmental relevance is not a concern. No known energy flow has been omitted in this study.
- Environmental relevance – If a flow meets the above criteria for exclusion, yet it is thought to potentially have a significant environmental impact, it is included. No known energy flow has been omitted in this study.
- Hazardous and toxic materials – The study shall include all hazardous and toxic materials in the inventory therefore the cutoff rules shall not apply to such substances. No substances required to be reported as hazardous are associated with the production of this product including upstream raw material supply and raw material manufacturing.
- The sum of the neglected material flows does not exceed 5% of mass, energy or environmental relevance for flows indirectly related to the process (e.g., operating materials). No known mass flow has been omitted in this study.

In this report, no known mass and energy flows are deliberately excluded; therefore, these criteria have been met. The completeness of the bill of materials defined in this report satisfies the above-defined cut-off criteria.

### 3.5. Allocation

Whenever a system boundary is crossed, environmental inputs and outputs have to be assigned to the different products. Where multi-inputs or multi-outputs are considered, the same applies. The PCR prescribes to report where and how allocation occurs in the modeling of the LCA. No recycled materials are used in the product system, and there were no co-products manufactured.

The manufacturing facility produces five distinct types of rainscreen cladding support systems, each with different configurations. Despite their design differences, all five systems undergo similar manufacturing operations within the facility. As a result, the annual manufacturing resource consumption, including electricity and ancillary materials, was distributed evenly across all five system types to ensure a consistent and fair allocation method.

The allocation of manufacturing resources was based on the total annual linear foot production of each system type. Linear foot production was chosen as the primary allocation metric because it represents manufacturing efforts, considering factors such as material throughput and processing time. Each system type received a proportional share of the total facility-wide manufacturing resources based on its contribution to the overall linear foot output.

For the MFI® system, a further refinement in allocation was necessary due to the presence of two distinct components: MFI rails and MFI brackets. Since these components differ in mass and production volumes, the electricity allocated to the MFI® system was further distributed between MFI rails and MFI brackets based on their respective annual in-house mass production values. This secondary allocation step ensured that electricity consumption was assigned in proportion to the actual manufacturing effort associated with each component.

By implementing a two-step allocation approach, first by using linear foot production for system-level allocation and then mass-based allocation for intra-system distribution (for the MFI® system), the methodology ensures an equitable and representative distribution of manufacturing resource consumption across all products and subcomponents. This approach aligns with ISO 21930:2017 by applying physical relationships to allocate resources, maintaining transparency, relevance, and accuracy in impact distribution.

### 3.6. Discussion of data quality

Inventory data quality is judged by its precision (measured, calculated, or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied on a study serving as a data source), and representativeness (geographical, temporal, and technological).

To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the ecoinvent v3.10, US-EI 2.2, and Industry data 2.0 databases were used.

#### ***Precision and completeness***

- *Precision:* As the relevant foreground data is primary data or modeled based on primary information sources of the owner of the technology, precision is considered to be high. Background data are from the ecoinvent v3.10, US-EI 2.2, and Industry data 2.0 databases with documented precision to the extent available.
- *Completeness:* Sustainable Minds worked with KWS and its suppliers to obtain a comprehensive set of primary data associated with the manufacturing processes and material compositions. The product system was checked for mass balance and completeness of the inventory. The data set was considered complete based on our understanding of the manufacturing site and a review with key stakeholders on the KWS team, and cut-off criteria were observed consistent with those prescribed in the PCR. Besides capital equipment, no data was knowingly omitted.

#### ***Consistency and reproducibility***

- *Consistency:* Primary data were collected with a similar level of detail, while background data were sourced primarily from the ecoinvent database. Other databases were used if data were not available in ecoinvent or the data set was judged to be more representative. Other methodological choices were made consistently throughout the model.

- *Reproducibility:* Reproducibility is warranted as much as possible through the disclosure of input-output data, data set choices, and modeling approaches in this report. Based on this information, a knowledgeable third party should be able to approximate the results of this study using the same data and modeling approaches.

#### **Representativeness**

- *Temporal:* All primary data were collected from January 2024 through December 2024, ensuring the representativeness of the manufacturing process. Secondary data were obtained from the ecoinvent v3.10, US-EI 2.2, and Industry data 2.0 databases and are typically representative of recent years. Temporal representativeness is therefore considered to be good.
- *Geographical:* Primary data are representative of production in Deer Park, WA. Secondary data were collected specific to the country under study. Where country-specific data were unavailable, global or rest-of-world averages were used to represent production in those locations. Geographical representativeness is therefore considered to be very good.
- *Technological:* All primary and secondary data were modeled to be specific to the technologies under study. Technological representativeness is considered to be very good.

### **3.7. Comparability**

ISO 21930:2017 section 5.5 highlights the following limitations and clarifications in EPD comparability: EPDs are comparable only if they use the same PCR (or sub-category PCR where applicable), include all relevant information modules, and are based on equivalent scenarios with respect to the context of construction works.

EPDs can only be compared when the same functional requirements between products are ensured and the requirements of ISO 21930:2017 section 5.5 are met. However, variations and deviations are possible. For example, different LCA software and background LCI data sets may lead to different results for the life cycle stages declared.

### **3.8. Assumptions and limitations**

A life cycle assessment of a product system is broad and complex, and it inherently requires assumptions and simplifications. The following limitations of this study should be recognized:

- The products evaluated in this report may optionally be coated with a black PVDF coating, which was excluded from this analysis.
- Primary data were modeled based on information provided by KWS for calendar year 2024. However, upstream supply chain data are subject to variability, which may impact the accuracy of the results.
- Upstream suppliers were contacted to gather information on component processing, including manufacturing activities, waste handling, and scrap rates. However, the data provided are based on estimates rather than primary data collected directly from the upstream facilities.
- Due to the unavailability of separate electricity data for each system type, electricity consumption in the manufacturing facility was allocated proportionately based on the linear foot production of each system type.

However, slight deviations may exist between system types, which could affect the accuracy of the allocation.

- Generic data sets were used for material inputs, transportation, and waste processing, which are considered to be of good quality. However, actual impacts from material suppliers, transport carriers, and local waste processing may vary, potentially affecting the accuracy of the results.
- The impact assessment methodology categories do not represent all possible environmental impact categories.
- Characterization factors used within the impact assessment methodology may contain varying levels of uncertainty.
- LCA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins, or risks.
- No "green power" is used in this LCA.
- No renewable certificates or purchased CO<sub>2</sub> offsets are included in the LCA.

# 4 IMPACT ASSESSMENT METHODS

## 4.1. Impact assessment characterization

The environmental indicators as required by the PCR are included as well as other indicators required to use the SM2013 Methodology [6] (see Table 13). The impact indicators are derived using the 100-year time horizon<sup>1</sup> factors, where relevant, as defined by TRACI 2.1 classification and characterization [7]. Long-term emissions (>100 years) are not taken into consideration in the impact estimate. USEtox indicators<sup>2</sup> are used to evaluate toxicity. Emissions from waste disposal are considered part of the product system under study, according to the “polluter pays principle”.

**Table 13.** Selected impact categories and units

Impact category	Unit	Description
Acidification	kg SO <sub>2</sub> eq (sulphur dioxide)	Acidification processes increase the acidity of water and soil systems and cause damage to lakes, streams, rivers and various plants and animals as well as building materials, paints, and other human-built structures.
Ecotoxicity	CTUe	Ecotoxicity causes negative impacts to ecological receptors and, indirectly, to human receptors through the impacts to the ecosystem.
Eutrophication	kg N eq (nitrogen)	Eutrophication is the enrichment of an aquatic ecosystem with nutrients (nitrates and phosphates) that accelerate biological productivity (growth of algae and weeds) and an undesirable accumulation of algal biomass.
Global warming	kg CO <sub>2</sub> eq (carbon dioxide)	Global warming is an average increase in the temperature of the atmosphere near the Earth’s surface and in the troposphere.
Ozone depletion	kg CFC-11 eq	Ozone depletion is the reduction of ozone in the stratosphere caused by the release of ozone depleting chemicals.
Carcinogenics	CTUh	Carcinogens have the potential to form cancers in humans.
Non-carcinogenics	CTUh	Non-Carcinogens have the potential to cause non-cancerous adverse impacts to human health.
Respiratory effects	kg PM <sub>2.5</sub> eq (fine particulates)	Particulate matter concentrations have a strong influence on chronic and acute respiratory symptoms and mortality rates.
Smog	kg O <sub>3</sub> eq (ozone)	Smog formation (photochemical oxidant formation) is the formation of ozone molecules in the troposphere by complex chemical reactions.
Fossil fuel depletion	MJ surplus	Fossil fuel depletion is the surplus energy to extract minerals and fossil fuels.

With respect to global warming potential, biogenic carbon is included in impact category calculations. The biogenic carbon measured in this study originates from packaging materials, and none of the raw materials used in the rainscreen cladding support systems are expected to contain biogenic carbon. Greenhouse gas emissions from land-use change are expected to be insignificant and were not reported. Carbon emissions during carbonation and calcination are also considered in this study; however, no carbonation or calcination is expected to occur during the production and manufacture of rainscreen cladding support systems.

<sup>1</sup> The 100-year period relates to the period in which the environmental impacts are modeled. This is different from the time period of the declared unit. The two periods are related as follows: all environmental impacts that are created in the period of the declared unit are modeled through life cycle impact assessment using a 100-year time horizon to understand the impacts that take place.

<sup>2</sup> USEtox is available in TRACI and at <http://www.usetox.org/>

It shall be noted that the above impact categories represent impact potentials. They are approximations of environmental impacts that could occur if the emitted molecules follow the underlying impact pathway and 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 chosen functional unit (relative approach).

The results from the impact assessment indicate potential environmental effects and do not predict actual impacts on category endpoints, the exceedance of thresholds, or safety margins or risks.

#### 4.2. Normalization and weighting

To arrive at a single score indicator, normalization [8] and weighting [9] as shown in Table 14 conforming to the SM 2013 Methodology were applied. The SM 2013 Methodology uses TRACI 2.1 impact categories developed by U.S. EPA, and North American normalization and weighting values developed by EPA and NIST respectively, to calculate single figure LCA results. Sustainable Minds recognizes that weighting is socially defined based on the importance that society attaches to the different environmental impact categories. However, these single score indicators serve as an easy starting point to get to know the product under consideration across all impact categories, rather than focusing all efforts on just one impact category (like global warming potential). The interpretation of the results starts with the Sustainable Minds single score results and then allows users to further explore the underlying impact categories individually. Details including the characterization models, factors, and methods used, including all assumptions and limitations, can be found in the SM 2013 Methodology Report [6].

**Table 14.** Normalization and weighting factors

<b>Impact category</b>	<b>Normalization</b>	<b>Weighting (%)</b>
Acidification	90.9	3.6
Ecotoxicity	11000	8.4
Eutrophication	21.6	7.2
Global warming	24200	34.9
Ozone depletion	0.161	2.4
Carcinogenics	5.07E-05	9.6
Non-carcinogenics	1.05E-03	6.0
Respiratory effects	24.3	10.8
Smog	1390	4.8
Fossil fuel depletion	17300	12.1

# 5 ASSESSMENT AND INTERPRETATION

This chapter includes the results from the LCA for the products studied. It details the results per declared unit, outlines the sensitivity analysis, and concludes with recommendations.

## 5.1. Data quality assessment

The quality of inventory data is evaluated based on its precision, completeness, consistency, and representativeness. The data used in this study is regarded as reliable and representative of the described systems, as well as their geographical, temporal, and technological contexts. When direct measurements were unavailable, the best engineering estimates based on actual production were applied. Every effort was made to ensure the highest data quality.

## 5.2. Resource use and waste flows

Resource use indicators, output flows and waste category indicators, and carbon emissions and removals are presented in this section. These life cycle inventory (LCI) indicators reflect the flows from and to nature for the product system, prior to characterization using an impact assessment methodology to calculate life cycle impact assessment (LCIA) results (as shown in section 5.3).

LCI flows were calculated with the help of American Center for Life Cycle Assessment's (ACLCA) guidance for calculating the ISO 21930:2017 metrics [10]. The consumption of freshwater indicator, which was calculated in accordance with this guidance, is reported in compliance with ISO 14046. Use of renewable and non-renewable energy resources with energy content were calculated using the Cumulative Energy Demand (LHV) impact assessment methodology [11]. Abiotic depletion potential was calculated using the CML impact assessment methodology [12]. LCI flows were reported in conformance to ISO 21930:2017.

Resource use indicators represent the amount of materials consumed to produce not only the product itself but also the raw materials, electricity, natural gas, etc. that go into the product's life cycle.

Primary energy is an energy form found in nature that has not been subjected to any conversion or transformation process and is expressed in energy demand from renewable and non-renewable resources. Efficiencies in energy conversion are considered when calculating primary energy demand from process energy consumption. Water use represents the total water used over the entire life cycle. No renewable energy was used in production beyond that accounted for in the eGRID data set, and no energy was recovered.

Hazardous and non-hazardous wastes are calculated based on the amount of waste generated during the life cycle of each product studied, mainly during the manufacturing of the products. All waste treatments in models were considered based on actual facility activities and the assumptions mentioned in the PCR. Waste treatments included within the system boundary are reported. Unrecyclable waste is incinerated. Table 15 represents all the resource use and waste flow indicators, with the acronyms used, evaluated in this study.

**Table 15.** Resource use and waste flow indicators

<b>Indicators</b>	<b>Acronyms used</b>
<b><i>Resource use indicators</i></b>	
Renewable primary energy used as energy carrier (fuel)	<b>RPR<sub>E</sub></b>
Renewable primary resources with energy content used as material	<b>RPR<sub>M</sub></b>
Total use of renewable primary resources with energy content	<b>RPR<sub>total</sub></b>
Non-renewable primary resources used as an energy carrier (fuel)	<b>NRPR<sub>E</sub></b>
Non-renewable primary resources with energy content used as material	<b>NRPR<sub>M</sub></b>
Total use of non-renewable primary resources with energy content	<b>NRPR<sub>total</sub></b>
Secondary materials	<b>SM</b>
Renewable secondary fuels	<b>RSF</b>
Non-renewable secondary fuels	<b>NRSF</b>
Recovered energy	<b>RE</b>
Use of net fresh water resources	<b>FW</b>
Abiotic depletion potential for fossil resources	<b>ADPf</b>
<b><i>Output flows and waste category indicators</i></b>	
Hazardous waste disposed	<b>HWD</b>
Non-hazardous waste disposed	<b>NHWD</b>
High-level radioactive waste, conditioned, to final repository	<b>HLRW</b>
Intermediate- and low-level radioactive waste, conditioned, to final repository	<b>ILLRW</b>
Components for re-use	<b>CRU</b>
Materials for recycling	<b>MR</b>
Materials for energy recovery	<b>MER</b>
Exported energy	<b>EE</b>
<b><i>Carbon emissions and removals</i></b>	
Biogenic Carbon Removal from Product	<b>BCRP</b>
Biogenic Carbon Emission from Product	<b>BCEP</b>
Biogenic Carbon Removal from Packaging	<b>BCRK</b>
Biogenic Carbon Emission from Packaging	<b>BCEK</b>
Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	<b>CBCEW</b>
Calcination Carbon Emissions	<b>CCE</b>
Carbonation Carbon Removals	<b>CCR</b>
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	<b>CWNR</b>

Resource use, output flows, waste categories, and carbon emissions & removals for each rainscreen cladding support systems type have been tabulated in the sections below.

### 5.2.1. CI<sup>®</sup> system

Table 16 shows resource use, output and waste flows, and carbon emissions and removals for the CI<sup>®</sup> system per declared unit.

**Table 16.** Resource use, output and waste flows, and carbon emissions and removals for CI<sup>®</sup> system per declared unit

Parameter	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
<b>Resource use indicators</b>					
RPR <sub>E</sub>	MJ, LHV	1.83E+00	4.22E-03	2.07E+00	<b>3.90E+00</b>
RPR <sub>M</sub>	MJ, LHV	0	0	0	<b>0</b>
RPR <sub>total</sub>	MJ, LHV	1.83E+00	4.22E-03	2.07E+00	<b>3.90E+00</b>
NRPR <sub>E</sub>	MJ, LHV	3.72E+01	2.58E+00	1.01E+00	<b>4.08E+01</b>
NRPR <sub>M</sub>	MJ, LHV	0	0	0	<b>0</b>
NRPR <sub>total</sub>	MJ, LHV	3.72E+01	2.58E+00	1.01E+00	<b>4.08E+01</b>
SM	kg	0	0	0	<b>0</b>
RSF	MJ, LHV	0	0	0	<b>0</b>
NRSF	MJ, LHV	0	0	0	<b>0</b>
RE	MJ, LHV	0	0	0	<b>0</b>
FW	m <sup>3</sup>	7.74E+00	2.10E-02	1.67E+00	<b>9.43E+00</b>
ADPf	MJ, LHV	3.56E+01	2.57E+00	9.33E-01	<b>3.91E+01</b>
<b>Output flows and waste category indicators</b>					
HWD	kg	0	0	0	<b>0</b>
NHWD	kg	0	0	0	<b>0</b>
HLRW	kg	6.62E-06	3.27E-08	3.10E-07	<b>6.97E-06</b>
ILLRW	kg	1.43E-05	6.25E-08	6.72E-07	<b>1.50E-05</b>
CRU	kg	0	0	0	<b>0</b>
MR	kg	2.10E-02	0	4.41E-02	<b>6.50E-02</b>
MER	kg	0	0	6.48E-03	<b>6.48E-03</b>
EE	MJ	0	0	0	<b>0</b>
<b>Carbon emissions and removals</b>					
BCRP	kg CO <sub>2</sub>	0	0	0	<b>0</b>
BCEP	kg CO <sub>2</sub>	0	0	0	<b>0</b>
BCRK	kg CO <sub>2</sub>	0	0	-1.13E-01	<b>-1.13E-01</b>
BCEK	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CBCEW	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CCE	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CCR	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CWNR	kg CO <sub>2</sub>	0	0	0	<b>0</b>

### 5.2.2. HCl system

Table 17 shows resource use, output and waste flows, and carbon emissions and removals for the HCl system per declared unit.

**Table 17.** Resource use, output and waste flows, and carbon emissions and removals for HCl system per declared unit

Parameter	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
<b>Resource use indicators</b>					
RPR <sub>E</sub>	MJ, LHV	2.48E+00	5.71E-03	2.60E+00	<b>5.08E+00</b>
RPR <sub>M</sub>	MJ, LHV	0	0	0	<b>0</b>
RPR <sub>total</sub>	MJ, LHV	2.48E+00	5.71E-03	2.60E+00	<b>5.08E+00</b>
NRPR <sub>E</sub>	MJ, LHV	5.03E+01	3.49E+00	1.19E+00	<b>5.50E+01</b>
NRPR <sub>M</sub>	MJ, LHV	0	0	0	<b>0</b>
NRPR <sub>total</sub>	MJ, LHV	5.03E+01	3.49E+00	1.19E+00	<b>5.50E+01</b>
SM	kg	0	0	0	<b>0</b>
RSF	MJ, LHV	0	0	0	<b>0</b>
NRSF	MJ, LHV	0	0	0	<b>0</b>
RE	MJ, LHV	0	0	0	<b>0</b>
FW	m <sup>3</sup>	1.05E+01	2.85E-02	1.72E+00	<b>1.22E+01</b>
ADPf	MJ, LHV	4.82E+01	3.48E+00	1.10E+00	<b>5.28E+01</b>
<b>Output flows and waste category indicators</b>					
HWD	kg	0	0	0	<b>0</b>
NHWD	kg	0	0	0	<b>0</b>
HLRW	kg	8.97E-06	4.43E-08	3.59E-07	<b>9.37E-06</b>
ILLRW	kg	1.93E-05	8.47E-08	7.76E-07	<b>2.02E-05</b>
CRU	kg	0	0	0	<b>0</b>
MR	kg	2.84E-02	0	1.62E-01	<b>1.90E-01</b>
MER	kg	0	0	6.48E-03	<b>6.48E-03</b>
EE	MJ	0	0	0	<b>0</b>
<b>Carbon emissions and removals</b>					
BCRP	kg CO <sub>2</sub>	0	0	0	<b>0</b>
BCEP	kg CO <sub>2</sub>	0	0	0	<b>0</b>
BCRK	kg CO <sub>2</sub>	0	0	-1.46E-01	<b>-1.46E-01</b>
BCEK	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CBCEW	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CCE	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CCR	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CWNR	kg CO <sub>2</sub>	0	0	0	<b>0</b>

### 5.2.3. ThermaZee®

Table 18 shows resource use, output and waste flows, and carbon emissions and removals for ThermaZee® per declared unit.

**Table 18.** Resource use, output and waste flows, and carbon emissions and removals for ThermaZee® per declared unit

Parameter	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
<b>Resource use indicators</b>					
RPR <sub>E</sub>	MJ, LHV	2.73E+00	6.10E-03	2.00E+00	<b>4.74E+00</b>
RPR <sub>M</sub>	MJ, LHV	0	0	0	<b>0</b>
RPR <sub>total</sub>	MJ, LHV	2.73E+00	6.10E-03	2.00E+00	<b>4.74E+00</b>
NRPR <sub>E</sub>	MJ, LHV	6.05E+01	3.73E+00	1.14E+00	<b>6.54E+01</b>
NRPR <sub>M</sub>	MJ, LHV	0	0	0	<b>0</b>
NRPR <sub>total</sub>	MJ, LHV	6.05E+01	3.73E+00	1.14E+00	<b>6.54E+01</b>
SM	kg	0	0	0	<b>0</b>
RSF	MJ, LHV	0	0	0	<b>0</b>
NRSF	MJ, LHV	0	0	0	<b>0</b>
RE	MJ, LHV	0	0	0	<b>0</b>
FW	m <sup>3</sup>	1.14E+01	3.04E-02	1.67E+00	<b>1.31E+01</b>
ADPf	MJ, LHV	5.79E+01	3.72E+00	1.06E+00	<b>6.27E+01</b>
<b>Output flows and waste category indicators</b>					
HWD	kg	0	0	0	<b>0</b>
NHWD	kg	0	0	0	<b>0</b>
HLRW	kg	9.88E-06	4.72E-08	3.06E-07	<b>1.02E-05</b>
ILLRW	kg	2.13E-05	9.03E-08	6.64E-07	<b>2.21E-05</b>
CRU	kg	0	0	0	<b>0</b>
MR	kg	3.79E-02	0	6.93E-01	<b>7.31E-01</b>
MER	kg	0	0	6.48E-03	<b>6.48E-03</b>
EE	MJ	0	0	0	<b>0</b>
<b>Carbon emissions and removals</b>					
BCRP	kg CO <sub>2</sub>	0	0	0	<b>0</b>
BCEP	kg CO <sub>2</sub>	0	0	0	<b>0</b>
BCRK	kg CO <sub>2</sub>	0	0	-1.09E-01	<b>-1.09E-01</b>
BCEK	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CBCEW	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CCE	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CCR	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CWNR	kg CO <sub>2</sub>	0	0	0	<b>0</b>

#### 5.2.4. PanelRail® & RevealRail

Table 19 shows resource use, output and waste flows, and carbon emissions and removals for PanelRail® & RevealRail per declared unit.

**Table 19.** Resource use, output and waste flows, and carbon emissions and removals for PanelRail® & RevealRail per declared unit

Parameter	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
<b>Resource use indicators</b>					
RPR <sub>E</sub>	MJ, LHV	2.03E+00	4.67E-03	2.07E+00	<b>4.10E+00</b>
RPR <sub>M</sub>	MJ, LHV	0	0	0	<b>0</b>
RPR <sub>total</sub>	MJ, LHV	2.03E+00	4.67E-03	2.07E+00	<b>4.10E+00</b>
NRPR <sub>E</sub>	MJ, LHV	4.12E+01	2.86E+00	1.05E+00	<b>4.51E+01</b>
NRPR <sub>M</sub>	MJ, LHV	0	0	0	<b>0</b>
NRPR <sub>total</sub>	MJ, LHV	4.12E+01	2.86E+00	1.05E+00	<b>4.51E+01</b>
SM	kg	0	0	0	<b>0</b>
RSF	MJ, LHV	0	0	0	<b>0</b>
NRSF	MJ, LHV	0	0	0	<b>0</b>
RE	MJ, LHV	0	0	0	<b>0</b>
FW	m <sup>3</sup>	8.58E+00	2.33E-02	1.67E+00	<b>1.03E+01</b>
ADPf	MJ, LHV	3.95E+01	2.85E+00	9.70E-01	<b>4.33E+01</b>
<b>Output flows and waste category indicators</b>					
HWD	kg	0	0	0	<b>0</b>
NHWD	kg	0	0	0	<b>0</b>
HLRW	kg	7.34E-06	3.62E-08	3.10E-07	<b>7.69E-06</b>
ILLRW	kg	1.58E-05	6.93E-08	6.73E-07	<b>1.66E-05</b>
CRU	kg	0	0	0	<b>0</b>
MR	kg	2.32E-02	0	2.17E-01	<b>2.41E-01</b>
MER	kg	0	0	6.48E-03	<b>6.48E-03</b>
EE	MJ	0	0	0	<b>0</b>
<b>Carbon emissions and removals</b>					
BCRP	kg CO <sub>2</sub>	0	0	0	<b>0</b>
BCEP	kg CO <sub>2</sub>	0	0	0	<b>0</b>
BCRK	kg CO <sub>2</sub>	0	0	-1.13E-01	<b>-1.13E-01</b>
BCEK	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CBCEW	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CCE	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CCR	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CWNR	kg CO <sub>2</sub>	0	0	0	<b>0</b>

### 5.2.5. MFI<sup>®</sup> system

Table 20 shows resource use, output and waste flows, and carbon emissions and removals for the MFI<sup>®</sup> system per declared unit.

**Table 20.** Resource use, output and waste flows, and carbon emissions and removals for MFI<sup>®</sup> system per declared unit

Parameter	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
<b>Resource use indicators</b>					
RPR <sub>E</sub>	MJ, LHV	2.21E+00	4.50E-03	1.71E+00	<b>3.93E+00</b>
RPR <sub>M</sub>	MJ, LHV	0	0	0	<b>0</b>
RPR <sub>total</sub>	MJ, LHV	2.21E+00	4.50E-03	1.71E+00	<b>3.93E+00</b>
NRPR <sub>E</sub>	MJ, LHV	4.20E+01	2.75E+00	1.26E+00	<b>4.60E+01</b>
NRPR <sub>M</sub>	MJ, LHV	0	0	0	<b>0</b>
NRPR <sub>total</sub>	MJ, LHV	4.20E+01	2.75E+00	1.26E+00	<b>4.60E+01</b>
SM	kg	0	0	0	<b>0</b>
RSF	MJ, LHV	0	0	0	<b>0</b>
NRSF	MJ, LHV	0	0	0	<b>0</b>
RE	MJ, LHV	0	0	0	<b>0</b>
FW	m <sup>3</sup>	9.49E+00	2.24E-02	1.52E+00	<b>1.10E+01</b>
ADPf	MJ, LHV	4.03E+01	2.74E+00	1.18E+00	<b>4.42E+01</b>
<b>Output flows and waste category indicators</b>					
HWD	kg	0	0	0	<b>0</b>
NHWD	kg	0	0	0	<b>0</b>
HLRW	kg	7.45E-06	3.49E-08	2.99E-07	<b>7.78E-06</b>
ILLRW	kg	1.61E-05	6.67E-08	6.59E-07	<b>1.68E-05</b>
CRU	kg	0	0	0	<b>0</b>
MR	kg	4.28E-02	0	1.02E-01	<b>1.45E-01</b>
MER	kg	0	0	6.48E-03	<b>6.48E-03</b>
EE	MJ	0	0	0	<b>0</b>
<b>Carbon emissions and removals</b>					
BCRP	kg CO <sub>2</sub>	0	0	0	<b>0</b>
BCEP	kg CO <sub>2</sub>	0	0	0	<b>0</b>
BCRK	kg CO <sub>2</sub>	0	0	-9.28E-02	<b>-9.28E-02</b>
BCEK	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CBCEW	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CCE	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CCR	kg CO <sub>2</sub>	0	0	0	<b>0</b>
CWNR	kg CO <sub>2</sub>	0	0	0	<b>0</b>

### 5.3. Life cycle impact assessment (LCIA)

It shall be reiterated at this point that the reported impact categories represent impact potentials; they are approximations of environmental impacts that could occur if the emitted molecules follow the underlying impact pathway and 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 chosen declared unit (relative approach). LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

Life cycle impact assessment (LCIA) results are shown per functional unit of both faucet types and toilet types. Unlike life cycle inventories, which only report sums for individual inventory flows, the LCIA includes a classification of individual emissions with regard to the impacts they are associated with and subsequently a characterization of the emissions by a factor expressing their respective contribution to the impact category indicator. The end result is a single metric for quantifying each potential impact, such as "Global Warming Potential".

The impact assessment results are calculated using characterization factors published by the United States Environmental Protection Agency. The TRACI 2.1 (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts 2.1) methodology is the most widely applied impact assessment method for U.S. LCA studies. The SM 2013 Methodology is also applied to come up with single score results for the sole purpose of representing total impacts per life cycle phase to explain where in the product life cycle greatest impacts are occurring and what is contributing to the impacts.

These eight TRACI impact categories are globally deemed mature enough to be included in Type III environmental declarations. Other categories are being developed and defined and LCA should continue making advances in their development; however, the EPD users shall not use additional measures for comparative purposes. All impact categories from TRACI are used to calculate single score millipoints using the SM2013 Methodology, but it should be noted that there are known limitations related to these impact categories due to their high degree of uncertainty.

It is important to note that the LCIA indicators for carcinogenics, non carcinogenics (CTUh), and ecotoxicity (CTUe) are subject to significant uncertainty. EN 15804 includes the following disclaimer: *"The results of this environmental impact indicator shall be used with care, as the uncertainties associated with these results are high, or there is limited experience with the indicator."*

#### 5.3.1. CI® system

The LCIA results for the CI® system per declared unit are shown in Table 21. An 18-gauge CI-GIRT® with a 0.75" depth configuration was selected as the representative product. The percent contribution of each of the cradle-to-gate life cycle modules is tabulated in Table 22 and is also presented in Figure 5.

The cradle-to-gate life cycle impacts of the product are largely driven by the material extraction and upstream production stage, which accounts for over 83% of the total environmental impacts across all impact categories except ozone depletion. Even for ozone depletion, A1 remains the dominant contributor, responsible for approximately 66% of the impacts, the highest among the A1-A3

modules. Within A1, the upstream extraction and production of steel coils, which occur entirely outside the KWS facility, drive approximately 99% of the impacts across all impact categories.

The transportation module (A2) is the next most significant contributor to several impact categories, including global warming potential, smog formation, acidification, eutrophication, respiratory effects, ecotoxicity, and fossil fuel depletion. The impacts in A2 primarily come from the upstream rail transport of steel coils to the slitting facility and the road transport of slitted coils to the KWS facility. Rail transport has a greater impact on smog, acidification, and eutrophication due to emissions from diesel locomotives and large-scale fuel combustion.

The manufacturing module (A3) surpasses A2 in ozone depletion, carcinogenics, and non-carcinogenics impacts. These are primarily driven by electricity consumption in various processing operations at the KWS facility, as well as the production (upstream) and supply of wooden crates used for packaging. Electricity use is a key contributor across several impact categories.

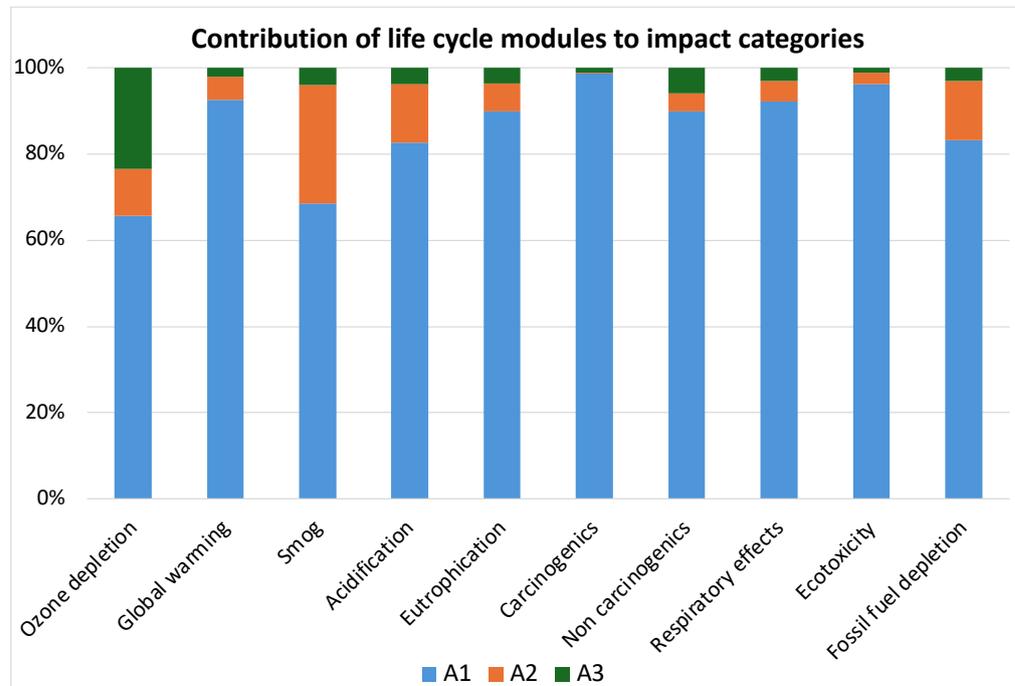
Overall, A1 is the most impactful life cycle module, mainly due to two activities: the upstream production of steel coils, including iron ore mining and refining, and the slitting operations at the slitting facility. In contrast, the transportation of materials to the KWS facility in A2 and the manufacturing activities within the KWS facility in A3 result in relatively minor impacts.

**Table 21.** Life cycle impact assessment results for CI<sup>®</sup> system per declared unit

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	kg CFC-11 eq	1.69E-08	2.83E-09	6.02E-09	<b>2.57E-08</b>
Global warming	kg CO2 eq	3.37E+00	1.93E-01	7.83E-02	<b>3.64E+00</b>
Smog	kg O3 eq	1.18E-01	4.71E-02	7.12E-03	<b>1.72E-01</b>
Acidification	kg SO2 eq	8.89E-03	1.46E-03	4.23E-04	<b>1.08E-02</b>
Eutrophication	kg N eq	1.27E-03	9.26E-05	5.06E-05	<b>1.42E-03</b>
Carcinogenics	CTUh	3.60E-08	6.69E-11	4.59E-10	<b>3.65E-08</b>
Non-carcinogenics	CTUh	2.05E-07	9.48E-09	1.38E-08	<b>2.29E-07</b>
Respiratory effects	kg PM2.5 eq	1.82E-03	9.25E-05	6.18E-05	<b>1.97E-03</b>
<b>Additional environmental information</b>					
Ecotoxicity	CTUe	6.16E+00	1.80E-01	7.03E-02	<b>6.41E+00</b>
Fossil fuel depletion	MJ surplus	2.23E+00	3.67E-01	8.42E-02	<b>2.68E+00</b>

**Table 22.** Percent contributions of life cycle modules for CI® system

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	%	65.59%	11.01%	23.40%	100%
Global warming	%	92.54%	5.31%	2.15%	100%
Smog	%	68.58%	27.29%	4.13%	100%
Acidification	%	82.53%	13.54%	3.93%	100%
Eutrophication	%	89.90%	6.53%	3.57%	100%
Carcinogenics	%	98.56%	0.18%	1.26%	100%
Non-carcinogenics	%	89.84%	4.14%	6.02%	100%
Respiratory effects	%	92.17%	4.69%	3.13%	100%
<b>Additional environmental information</b>					
Ecotoxicity	%	96.10%	2.81%	1.10%	100%
Fossil fuel depletion	%	83.15%	13.71%	3.14%	100%


**Figure 5.** Contribution analysis of impact categories for CI® system

The SM2013 Methodology single figure millipoint (mPt) score by life cycle module for this product is presented in Table 23. The raw material extraction and upstream production module (A1) dominates the results (~93%).

**Table 23.** SM millipoint scores for CI® system per declared unit

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
SM single figure score	mPts	2.11E-01	1.03E-02	4.77E-03	2.26E-01

These results have been reported for the 18-gauge CI-GIRT® with a 0.75" depth configuration. To accommodate other available CI® system configurations, scaling factors have been developed. These factors enable users to calculate LCIA results specific to their chosen configuration. Table 24 presents the scaling factors, which

when multiplied by the cradle-to-gate impact results of the representative product, yield the impacts for a given configuration.

**Table 24.** Scaling factors for CI<sup>®</sup> system configurations

Impact category	CI <sup>®</sup> system configurations		
	CI16*0.75	CI18*1.50	CI16*1.50
Ozone depletion	1.20	1.07	1.27
Global warming	1.25	1.09	1.38
Smog	1.25	1.09	1.40
Acidification	1.25	1.09	1.40
Eutrophication	1.25	1.09	1.40
Carcinogenics	1.25	1.09	1.41
Non-carcinogenics	1.25	1.09	1.36
Respiratory effects	1.25	1.09	1.40
Ecotoxicity	1.26	1.09	1.37
Fossil fuel depletion	1.25	1.09	1.34

### 5.3.2. HCl system

The LCIA results for the HCl system per declared unit are shown in Table 25. An 18-gauge HCl-GIRT with a 0.75" depth configuration was selected as the representative product for this system. The percent contribution of each of the cradle-to-gate life cycle modules is tabulated in Table 26 and shown in Figure 6.

The cradle-to-gate life cycle impacts of the product are largely driven by the material extraction and upstream production stage, which accounts for over 83% of the total environmental impacts across all impact categories but ozone depletion. Even for ozone depletion, A1 remains the dominant contributor, responsible for approximately 70% of the impacts, the highest among the A1-A3 modules. Within A1, the upstream extraction and production of slitted steel coils, which occur entirely outside the KWS facility, drive approximately 99% of the impacts across all impact categories.

The transportation module (A2) is the next most significant contributor to several impact categories, including global warming potential, smog formation, acidification, eutrophication, respiratory effects, ecotoxicity, and fossil fuel depletion. The impacts in A2 primarily come from the upstream rail transport of steel coils to the slitting facility and the road transport of slitted coils to the KWS facility. Rail transport has a greater impact on smog, acidification, and eutrophication due to emissions from diesel locomotives and large-scale fuel combustion.

The manufacturing module (A3) surpasses A2 in ozone depletion, carcinogenics, and non-carcinogenics impacts. These are primarily driven by electricity consumption in various processing operations at the KWS facility, as well as the production (upstream) and supply of wooden crates used for packaging. Electricity use is a key contributor across several impact categories.

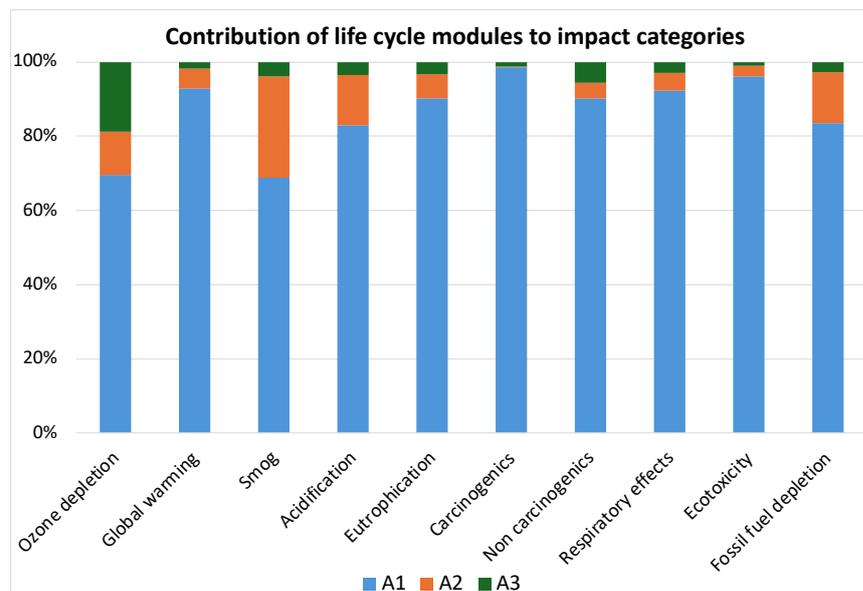
Overall, A1 is the most impactful life cycle module, mainly due to two activities: the upstream production of steel coils, including iron ore mining and refining, and the slitting operations at the slitting facility. In contrast, the transportation of materials to the KWS facility in A2 and the manufacturing activities within the KWS facility in A3 result in relatively minor impacts.

**Table 25.** Life cycle impact assessment results HCl system per declared unit

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	kg CFC-11 eq	2.28E-08	3.83E-09	6.19E-09	<b>3.29E-08</b>
Global warming	kg CO2 eq	4.56E+00	2.62E-01	9.13E-02	<b>4.92E+00</b>
Smog	kg O3 eq	1.60E-01	6.37E-02	9.01E-03	<b>2.33E-01</b>
Acidification	kg SO2 eq	1.20E-02	1.97E-03	5.05E-04	<b>1.45E-02</b>
Eutrophication	kg N eq	1.73E-03	1.25E-04	6.16E-05	<b>1.91E-03</b>
Carcinogenics	CTUh	4.87E-08	9.06E-11	5.54E-10	<b>4.94E-08</b>
Non-carcinogenics	CTUh	2.78E-07	1.28E-08	1.74E-08	<b>3.08E-07</b>
Respiratory effects	kg PM2.5 eq	2.46E-03	1.25E-04	7.78E-05	<b>2.66E-03</b>
<b>Additional environmental information</b>					
Ecotoxicity	CTUe	8.34E+00	2.44E-01	8.89E-02	<b>8.68E+00</b>
Fossil fuel depletion	MJ surplus	3.02E+00	4.97E-01	1.00E-01	<b>3.61E+00</b>

**Table 26.** Percent contributions of life cycle modules for HCl system

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	%	69.51%	11.66%	18.83%	<b>100%</b>
Global warming	%	92.82%	5.33%	1.86%	<b>100%</b>
Smog	%	68.76%	27.36%	3.87%	<b>100%</b>
Acidification	%	82.92%	13.60%	3.48%	<b>100%</b>
Eutrophication	%	90.23%	6.55%	3.22%	<b>100%</b>
Carcinogenics	%	98.69%	0.18%	1.12%	<b>100%</b>
Non-carcinogenics	%	90.21%	4.16%	5.63%	<b>100%</b>
Respiratory effects	%	69.51%	11.66%	18.83%	<b>100%</b>
<b>Additional environmental information</b>					
Ecotoxicity	%	92.37%	4.70%	2.92%	<b>100%</b>
Fossil fuel depletion	%	96.17%	2.81%	1.03%	<b>100%</b>


**Figure 6.** Contribution analysis of impact categories for HCl system

The SM2013 Methodology single figure millipoint (mPt) score by life cycle module for this product is presented in Table 27. The raw material extraction and upstream production module (A1) dominates the results (~94%).

**Table 27.** SM millipoint scores for HCl system per declared unit

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
SM single figure score	mPts	2.86E-01	1.40E-02	5.80E-03	<b>3.06E-01</b>

These results have been reported for the 18-gauge HCl-GIRT with a 0.75" depth configuration. To accommodate other available HCl system configurations, scaling factors have been developed which enable users to calculate LCIA results specific to their chosen configuration. Table 28 presents the scaling factors, which when multiplied by the cradle-to-gate impacts of the representative product, yield the impacts for a given configuration.

**Table 28.** Scaling factors for HCl system cladding support configurations

Impact category	HCl system cladding support configurations		
	HCl16*0.75	HCl18*1.50	HCl16*1.50
Ozone depletion	1.22	1.32	1.57
Global warming	1.27	1.38	1.68
Smog	1.27	1.38	1.68
Acidification	1.26	1.38	1.68
Eutrophication	1.27	1.38	1.68
Carcinogenics	1.27	1.38	1.68
Non-carcinogenics	1.27	1.38	1.69
Respiratory effects	1.27	1.38	1.68
Ecotoxicity	1.27	1.38	1.69
Fossil fuel depletion	1.26	1.38	1.68

### 5.3.3. ThermaZee®

The LCIA results for ThermaZee® per declared unit are shown in Table 29. A representative 18-gauge configuration with a 4" depth was selected for this system. The percent contribution of each of the cradle-to-gate life cycle modules is tabulated in Table 30 and is also presented in Figure 7.

The cradle-to-gate life cycle impacts of the product are largely driven by the material extraction and upstream production stage, which accounts for over 85% of the total environmental impacts across all impact categories except ozone depletion and smog. Even for ozone depletion and smog, A1 remains the dominant contributor, responsible for approximately 72% of the impacts, the highest among the A1-A3 modules. Within A1, the upstream extraction and production of steel coils, which occur entirely outside the KWS facility, drive approximately 90% of the impacts across all impact categories. Upstream production of isolators makes a small share in A1 impacts, less than 10% in most of the impact categories.

The transportation module (A2) is the next most significant contributor to several impact categories, including global warming potential, smog formation, acidification, eutrophication, respiratory effects, ecotoxicity, and fossil fuel depletion. The impacts in A2 primarily come from the upstream rail transport of steel coils to the

slitting facility and the road transport of slitted coils and isolators to the KWS facility. Rail transport has a greater impact on smog, acidification, and eutrophication due to emissions from diesel locomotives and large-scale fuel combustion.

The manufacturing module (A3) surpasses A2 in ozone depletion and carcinogenics impacts. These are primarily driven by electricity consumption in various processing operations at the KWS facility, as well as the production (upstream) and supply of wooden crates used for packaging. Electricity use is a key contributor across several impact categories.

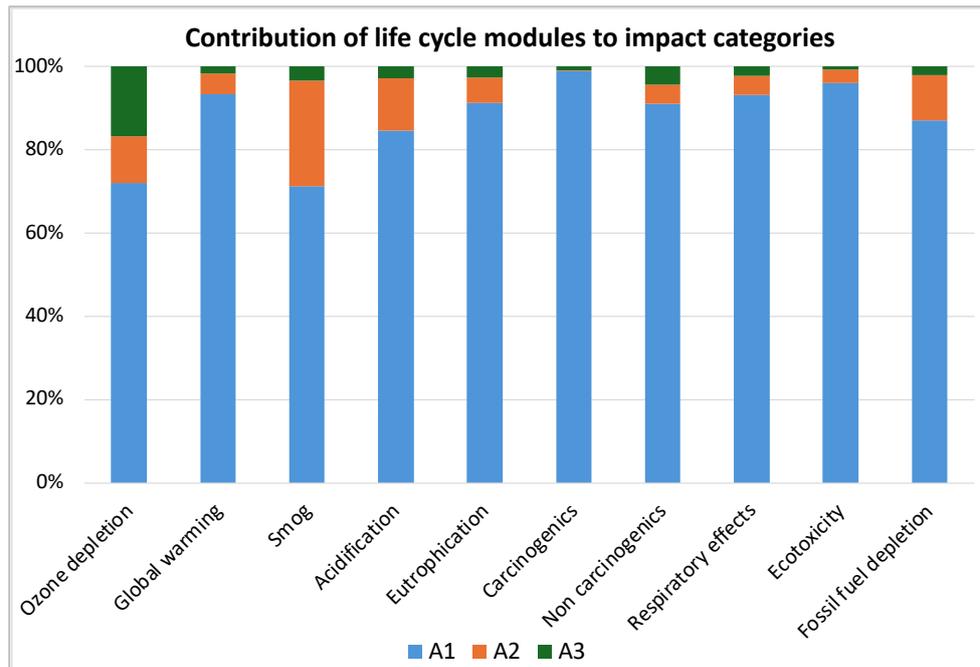
Overall, A1 is the most impactful life cycle module, mainly due to two activities: the upstream production of steel coils, including iron ore mining and refining, and the slitting operations at the slitting facility. In contrast, the transportation of materials to the KWS facility in A2 and the manufacturing activities within the KWS facility in A3 result in relatively minor impacts.

**Table 29.** Life cycle impact assessment results for ThermaZee® per declared unit

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	kg CFC-11 eq	2.66E-08	4.11E-09	6.18E-09	<b>3.68E-08</b>
Global warming	kg CO2 eq	5.11E+00	2.80E-01	8.76E-02	<b>5.48E+00</b>
Smog	kg O3 eq	1.82E-01	6.48E-02	8.52E-03	<b>2.55E-01</b>
Acidification	kg SO2 eq	1.37E-02	2.02E-03	4.66E-04	<b>1.62E-02</b>
Eutrophication	kg N eq	1.90E-03	1.28E-04	5.26E-05	<b>2.08E-03</b>
Carcinogenics	CTUh	5.20E-08	1.01E-10	4.49E-10	<b>5.25E-08</b>
Non-carcinogenics	CTUh	2.90E-07	1.48E-08	1.38E-08	<b>3.19E-07</b>
Respiratory effects	kg PM2.5 eq	2.73E-03	1.31E-04	6.64E-05	<b>2.93E-03</b>
<b>Additional environmental information</b>					
Ecotoxicity	CTUe	8.63E+00	2.84E-01	6.94E-02	<b>8.99E+00</b>
Fossil fuel depletion	MJ surplus	4.25E+00	5.31E-01	1.03E-01	<b>4.88E+00</b>

**Table 30.** Percent contributions of life cycle modules for ThermaZee®

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	%	72.09%	11.14%	16.77%	<b>100%</b>
Global warming	%	93.30%	5.10%	1.60%	<b>100%</b>
Smog	%	71.26%	25.40%	3.34%	<b>100%</b>
Acidification	%	84.69%	12.44%	2.88%	<b>100%</b>
Eutrophication	%	91.31%	6.16%	2.53%	<b>100%</b>
Carcinogenics	%	98.95%	0.19%	0.86%	<b>100%</b>
Non-carcinogenics	%	91.01%	4.66%	4.33%	<b>100%</b>
Respiratory effects	%	93.25%	4.48%	2.27%	<b>100%</b>
<b>Additional environmental information</b>					
Ecotoxicity	%	96.06%	3.16%	0.77%	<b>100%</b>
Fossil fuel depletion	%	87.02%	10.87%	2.10%	<b>100%</b>



**Figure 7.** Contribution analysis of impact categories for ThermaZee®

The SM2013 Methodology single figure millipoint (mPts) score by life cycle module for this product is presented in Table 31. The raw material extraction and upstream production module (A1) dominates the results (~94%).

**Table 31.** SM millipoint scores for ThermaZee® per declared unit

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
SM single figure score	mPts	3.15E-01	1.50E-02	5.10E-03	<b>3.35E-01</b>

These results have been reported for the 18-gauge configuration with a 4" depth. To accommodate other available ThermaZee® configurations, scaling factors have been developed which enable users to calculate LCIA results specific to their chosen configuration. Table 32 presents the scaling factors, which when multiplied by the cradle-to-gate impact results of the representative product, yield the impacts for a given configuration.

**Table 32.** Scaling factors for ThermaZee® configurations

Impact category	ThermaZee® cladding support configurations														
	18*1.5	16*1.5	18*2	16*2	18*2.5	16*2.5	18*3	16*3	18*3.5	16*3.5	16*4	18*4.5	16*4.5	18*5	16*5
Ozone depletion	0.97	1.10	0.97	1.28	1.02	1.29	1.01	1.31	1.04	1.40	1.33	1.07	1.42	1.13	1.29
Global warming	0.96	1.11	0.96	1.34	1.02	1.35	1.02	1.38	1.05	1.48	1.40	1.08	1.50	1.15	1.34
Smog	0.96	1.12	0.96	1.34	1.03	1.35	1.02	1.38	1.05	1.49	1.41	1.08	1.51	1.15	1.35
Acidification	0.96	1.11	0.96	1.33	1.02	1.35	1.02	1.38	1.05	1.48	1.40	1.08	1.50	1.15	1.34
Eutrophication	0.96	1.12	0.96	1.35	1.03	1.36	1.02	1.39	1.05	1.49	1.41	1.08	1.51	1.16	1.35
Carcinogenics	0.96	1.12	0.96	1.35	1.03	1.37	1.02	1.40	1.05	1.51	1.42	1.09	1.53	1.16	1.36
Non-carcinogenics	0.96	1.12	0.96	1.36	1.03	1.38	1.02	1.41	1.05	1.52	1.43	1.09	1.54	1.16	1.37
Respiratory effects	0.96	1.12	0.96	1.34	1.03	1.35	1.02	1.38	1.05	1.49	1.41	1.08	1.51	1.15	1.35
Ecotoxicity	0.96	1.12	0.96	1.36	1.03	1.38	1.02	1.41	1.05	1.52	1.43	1.09	1.54	1.16	1.37
Fossil fuel depletion	0.97	1.09	0.97	1.28	1.02	1.28	1.01	1.31	1.04	1.39	1.33	1.07	1.41	1.12	1.28

### 5.3.4. PanelRail® & RevealRail

The LCIA results for PanelRail® & RevealRail per declared unit are shown in Table 33. A representative 18-gauge configuration featuring a 2” face and a 0.75” depth was selected for this system. The percent contribution of each of the cradle-to-gate life cycle modules is tabulated in Table 34 and is also presented in Figure 8.

The cradle-to-gate life cycle impacts of the product are largely driven by the material extraction and upstream production stage, which accounts for over 83% of the total environmental impacts across all impact categories except ozone depletion and smog. Even for ozone depletion and smog, A1 remains the dominant contributor, responsible for approximately 68% of the impacts, the highest among the A1-A3 modules. Within A1, the upstream extraction and production of steel coils, which occur entirely outside the KWS facility, drive approximately 99% of the impacts across all impact categories.

The transportation module (A2) is the next most significant contributor to several impact categories, including global warming potential, smog formation, acidification, eutrophication, respiratory effects, ecotoxicity, and fossil fuel depletion. The impacts in A2 primarily come from the upstream rail transport of steel coils to the slitting facility and the road transport of slitted coils to the KWS facility. Rail transport has a greater impact on smog, acidification, and eutrophication due to emissions from diesel locomotives and large-scale fuel combustion.

The manufacturing module (A3) surpasses A2 in ozone depletion and carcinogenics impacts. These are primarily driven by electricity consumption in various processing operations at the KWS facility, as well as the production (upstream) and supply of wooden crates used for packaging. Electricity use is a key contributor across several impact categories.

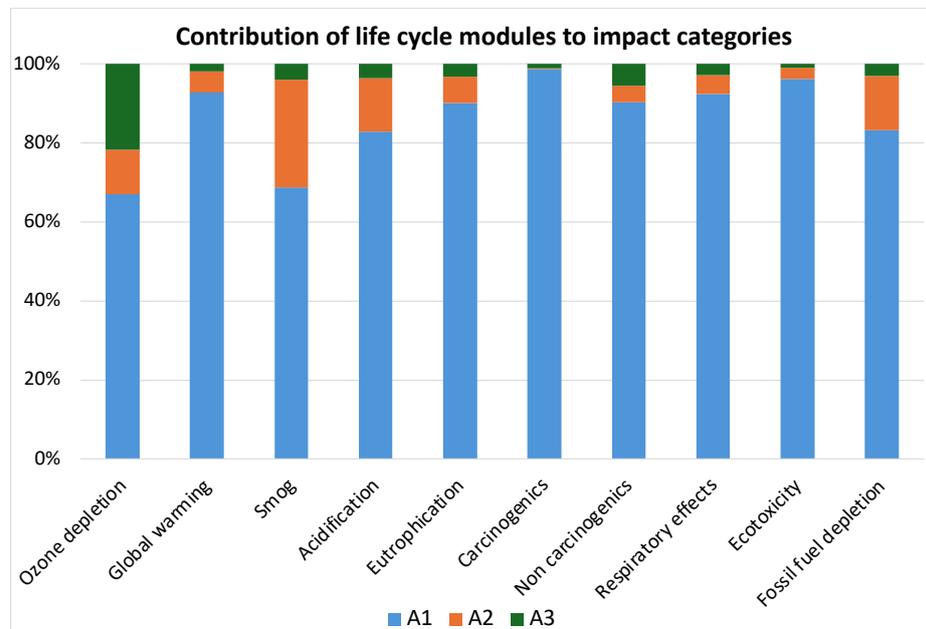
Overall, A1 is the most impactful life cycle module, mainly due to two activities: the upstream production of steel coils, including iron ore mining and refining, and the slitting operations at the slitting facility. In contrast, the transportation of materials to the KWS facility in A2 and the manufacturing activities within the KWS facility in A3 result in relatively minor impacts.

**Table 33.** Life cycle impact assessment results for PanelRail® & RevealRail per declared unit

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	kg CFC-11 eq	1.87E-08	3.14E-09	6.07E-09	<b>2.79E-08</b>
Global warming	kg CO2 eq	3.74E+00	2.14E-01	8.11E-02	<b>4.03E+00</b>
Smog	kg O3 eq	1.31E-01	5.22E-02	7.54E-03	<b>1.91E-01</b>
Acidification	kg SO2 eq	9.85E-03	1.62E-03	4.37E-04	<b>1.19E-02</b>
Eutrophication	kg N eq	1.41E-03	1.03E-04	5.15E-05	<b>1.57E-03</b>
Carcinogenics	CTUh	3.99E-08	7.41E-11	4.59E-10	<b>4.04E-08</b>
Non-carcinogenics	CTUh	2.28E-07	1.05E-08	1.39E-08	<b>2.52E-07</b>
Respiratory effects	kg PM2.5 eq	2.01E-03	1.03E-04	6.35E-05	<b>2.18E-03</b>
<b>Additional environmental information</b>					
Ecotoxicity	CTUe	6.83E+00	1.99E-01	7.07E-02	<b>7.10E+00</b>
Fossil fuel depletion	MJ surplus	2.47E+00	4.07E-01	8.95E-02	<b>2.96E+00</b>

**Table 34.** Percent contributions of life cycle modules for PanelRail® & RevealRail

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	%	67.01%	11.24%	21.75%	100%
Global warming	%	92.67%	5.32%	2.01%	100%
Smog	%	68.71%	27.34%	3.95%	100%
Acidification	%	82.75%	13.58%	3.67%	100%
Eutrophication	%	90.17%	6.55%	3.29%	100%
Carcinogenics	%	98.68%	0.18%	1.14%	100%
Non-carcinogenics	%	90.32%	4.17%	5.51%	100%
Respiratory effects	%	92.38%	4.70%	2.91%	100%
<b>Additional environmental information</b>					
Ecotoxicity	%	96.20%	2.81%	1.00%	100%
Fossil fuel depletion	%	83.26%	13.73%	3.02%	100%


**Figure 8.** Contribution analysis of impact categories for PanelRail® & RevealRail

The SM2013 Methodology single figure millipoint (mPts) score by life cycle module for this product is presented in Table 35. The raw material extraction and upstream production module (A1) dominates the results (~93%).

**Table 35.** SM millipoint scores for PanelRail® & RevealRail per declared unit

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
SM single figure score	mPts	2.34E-01	1.14E-02	4.89E-03	2.50E-01

These results have been reported for an 18-gauge configuration, with a 2" face and a 0.75" depth. To accommodate other available configurations, scaling factors have been developed which enable users to calculate LCIA results specific to their chosen configuration. Table 36 presents the scaling factors, which when multiplied by the cradle-to-gate impact results of the representative product, yield the impacts for a given configuration.

**Table 36. Scaling factors for PanelRail® & RevealRail configurations**

Impact category	PanelRail® & RevealRail configurations																
	PR-2*16* 0.75	PR-2*18*1	PR-2*16*1	PR-2*18* 1.25	PR-2*16* 1.25	PR-2*18* 1.5	PR-2*16* 1.5	PR-2*18* 1.75	PR-2*16* 1.75	PR-3*18* 0.75	PR-3*16* 0.75	PR-4*18* 0.75	PR-4*16* 0.75	PR-5*18* 0.75	PR-5*16* 0.75	PR-5*18*1	PR-5*16*1
Ozone depletion	1.23	1.07	1.32	1.14	1.41	1.21	1.49	1.28	1.58	1.18	1.44	1.31	1.60	1.42	1.60	1.50	1.88
Global warming	1.28	1.09	1.39	1.17	1.50	1.26	1.60	1.35	1.71	1.22	1.55	1.38	1.75	1.52	1.75	1.61	2.08
Smog	1.29	1.09	1.39	1.17	1.50	1.26	1.60	1.35	1.72	1.22	1.55	1.38	1.75	1.53	1.75	1.62	2.08
Acidification	1.28	1.09	1.39	1.17	1.50	1.26	1.60	1.34	1.71	1.22	1.54	1.38	1.74	1.52	1.74	1.61	2.08
Eutrophication	1.29	1.09	1.39	1.17	1.50	1.26	1.60	1.35	1.72	1.22	1.55	1.38	1.75	1.53	1.75	1.61	2.08
Carcinogenics	1.29	1.09	1.39	1.17	1.51	1.26	1.61	1.35	1.72	1.22	1.55	1.38	1.75	1.53	1.75	1.62	2.09
Non-carcinogenics	1.29	1.09	1.39	1.17	1.51	1.26	1.61	1.35	1.72	1.23	1.55	1.38	1.75	1.53	1.75	1.62	2.09
Respiratory effects	1.29	1.09	1.39	1.17	1.51	1.26	1.61	1.35	1.72	1.22	1.55	1.38	1.75	1.53	1.75	1.62	2.09
Ecotoxicity	1.29	1.09	1.39	1.17	1.51	1.26	1.61	1.35	1.72	1.23	1.55	1.38	1.75	1.53	1.75	1.62	2.09
Fossil fuel depletion	1.28	1.09	1.39	1.17	1.50	1.26	1.60	1.34	1.71	1.22	1.54	1.38	1.74	1.52	1.74	1.61	2.08
Impact category	PanelRail® & RevealRail configurations																
	PR-5*18* 1.25	PR-5*16* 1.25	PR-5*18* 1.50	PR-5*16* 1.50	PR-5*18* 1.75	PR-5*16* 1.75	RR-5*18* 0.75	RR-5*16* 0.75	RR-5*18*1	RR-5*16*1	RR-5*18* 1.25	RR-5*16* 1.25	RR-5*18* 1.50	RR-5*16* 1.50	RR-5*18* 1.75	RR-5*16* 1.75	
Ozone depletion	1.56	1.97	1.63	2.05	1.69	2.14	1.23	1.50	1.27	1.55	1.34	1.64	1.41	1.73	1.48	1.82	
Global warming	1.69	2.19	1.78	2.29	1.86	2.40	1.28	1.61	1.33	1.68	1.42	1.79	1.50	1.90	1.59	2.01	
Smog	1.69	2.20	1.78	2.30	1.86	2.41	1.28	1.62	1.34	1.68	1.42	1.79	1.50	1.91	1.59	2.02	
Acidification	1.69	2.19	1.78	2.29	1.86	2.40	1.28	1.61	1.33	1.68	1.42	1.79	1.50	1.90	1.59	2.01	
Eutrophication	1.69	2.20	1.78	2.30	1.86	2.41	1.28	1.61	1.34	1.68	1.42	1.79	1.50	1.91	1.59	2.02	
Carcinogenics	1.70	2.20	1.79	2.30	1.86	2.41	1.28	1.62	1.34	1.68	1.43	1.80	1.51	1.91	1.60	2.02	
Non-carcinogenics	1.70	2.20	1.79	2.31	1.87	2.42	1.28	1.62	1.34	1.69	1.43	1.80	1.51	1.91	1.60	2.02	
Respiratory effects	1.70	2.20	1.79	2.30	1.86	2.41	1.28	1.62	1.34	1.68	1.43	1.80	1.51	1.91	1.60	2.02	
Ecotoxicity	1.70	2.20	1.79	2.31	1.87	2.42	1.28	1.62	1.34	1.69	1.43	1.80	1.51	1.91	1.60	2.02	
Fossil fuel depletion	1.69	2.19	1.78	2.29	1.85	2.40	1.28	1.61	1.33	1.68	1.42	1.79	1.50	1.90	1.59	2.01	

### 5.3.5. MFI® system

The LCIA results for the MFI® system per declared unit are shown in Table 37. A representative 16-gauge S-series rail and 2" depth S-series bracket configuration was selected for this system. The percent contribution of each of the cradle-to-gate life cycle modules is tabulated in Table 38 and is also presented in Figure 9.

The cradle-to-gate life cycle impacts of the product are largely driven by the material extraction and upstream production stage, which accounts for over 83% of the total environmental impacts across all impact categories except ozone depletion and smog. Even for ozone depletion and smog, A1 remains the dominant contributor, responsible for approximately 70% of the impacts, the highest among the A1-A3 modules. Within A1, the upstream extraction and production of steel coils for rails and steel sheets for brackets, which occur entirely outside the KWS facility, collectively drive most of the impacts across all impact categories.

The transportation module (A2) is the next most significant contributor to several impact categories, including global warming potential, smog formation, acidification, eutrophication, respiratory effects, ecotoxicity, and fossil fuel depletion. The impacts in A2 primarily come from the upstream rail transport of steel coils and

sheets to the slitting facility and the road transport of slitted coils and sheets to the KWS facility. Rail transport has a greater impact on smog, acidification, and eutrophication due to emissions from diesel locomotives and large-scale fuel combustion.

The manufacturing module (A3) surpasses A2 in ozone depletion, carcinogenics, and non carcinogenics impacts. These are primarily driven by electricity consumption in various processing operations at the KWS facility, as well as the production (upstream) and supply of wooden crates and polypropylene used for packaging. Electricity use is a key contributor across several impact categories.

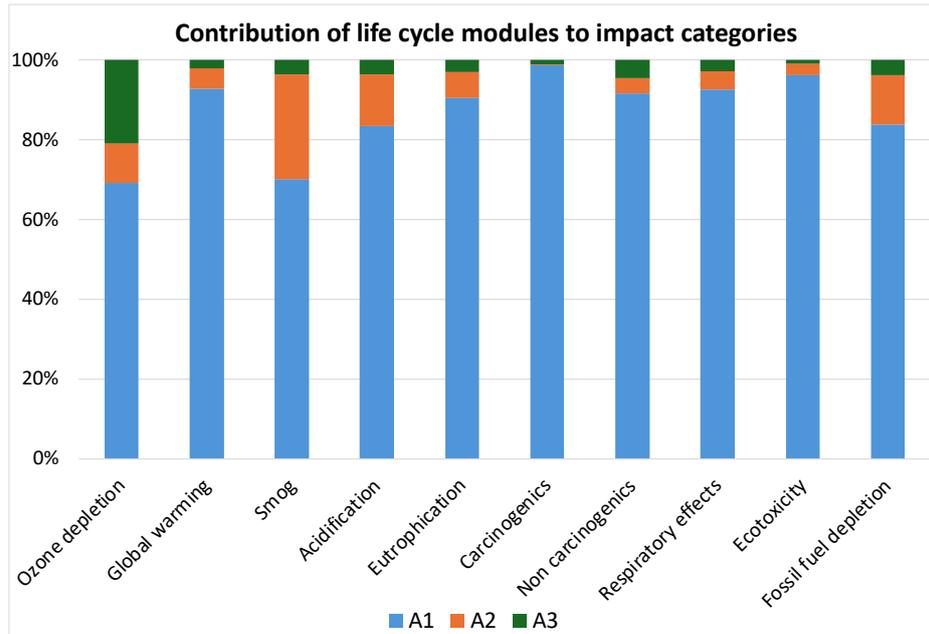
Overall, A1 is the most impactful life cycle module, mainly due to two activities: the upstream production of steel coils and sheets, including iron ore mining and refining, and the slitting operations at the slitting facility. In contrast, the transportation of materials to the KWS facility in A2 and the manufacturing activities within the KWS facility in A3 result in relatively minor impacts.

**Table 37.** Life cycle impact assessment results for MFI<sup>®</sup> system per declared unit

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	kg CFC-11 eq	2.09E-08	3.02E-09	6.30E-09	<b>3.03E-08</b>
Global warming	kg CO2 eq	3.71E+00	2.06E-01	8.26E-02	<b>4.00E+00</b>
Smog	kg O3 eq	1.33E-01	5.01E-02	6.66E-03	<b>1.90E-01</b>
Acidification	kg SO2 eq	9.88E-03	1.55E-03	4.14E-04	<b>1.18E-02</b>
Eutrophication	kg N eq	1.40E-03	9.85E-05	4.71E-05	<b>1.54E-03</b>
Carcinogenics	CTUh	4.02E-08	7.16E-11	4.10E-10	<b>4.07E-08</b>
Non-carcinogenics	CTUh	2.43E-07	1.02E-08	1.18E-08	<b>2.65E-07</b>
Respiratory effects	kg PM2.5 eq	2.00E-03	9.86E-05	5.92E-05	<b>2.16E-03</b>
<b>Additional environmental information</b>					
Ecotoxicity	CTUe	6.65E+00	1.93E-01	6.20E-02	<b>6.91E+00</b>
Fossil fuel depletion	MJ surplus	2.65E+00	3.92E-01	1.20E-01	<b>3.16E+00</b>

**Table 38.** Percent contributions of life cycle modules for MFI<sup>®</sup> system

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	%	69.21%	9.98%	20.81%	<b>100%</b>
Global warming	%	92.78%	5.16%	2.06%	<b>100%</b>
Smog	%	70.07%	26.41%	3.51%	<b>100%</b>
Acidification	%	83.40%	13.10%	3.50%	<b>100%</b>
Eutrophication	%	90.56%	6.39%	3.05%	<b>100%</b>
Carcinogenics	%	98.82%	0.18%	1.01%	<b>100%</b>
Non-carcinogenics	%	91.68%	3.84%	4.47%	<b>100%</b>
Respiratory effects	%	92.68%	4.57%	2.75%	<b>100%</b>
<b>Additional environmental information</b>					
Ecotoxicity	%	96.31%	2.88%	0.90%	<b>100%</b>
Fossil fuel depletion	%	83.80%	12.40%	3.80%	<b>100%</b>



**Figure 9.** Contribution analysis of impact categories for MFI® system

The SM2013 Methodology single figure millipoint (mPts) score by life cycle module for this product is presented in Table 39. In terms of single figure scores as well, the raw material extraction and upstream production module (A1) dominates the results (~94%).

**Table 39.** SM millipoint scores for MFI® system per declared unit

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
SM single figure score	mPts	2.35E-01	1.10E-02	4.77E-03	<b>2.51E-01</b>

These results have been reported for the 16-gauge S-series rail and 2” depth S-series bracket. To accommodate other available configurations, scaling factors have been developed which enable users to calculate LCIA results specific to their chosen configuration. Table 40 and

Table 41 present the scaling factors, which when multiplied by the cradle-to-gate impact results of the representative product, yield the impacts for a given configuration.

**Table 40.** Scaling factors for MFI® system configurations (S-Series)

Impact category	MFI® S-Series system with S 16 ga rail					MFI® S-Series system with S 18 ga rail					
	3S bracket	3.5S bracket	4S bracket	5S bracket	6S bracket	2S bracket	3S bracket	3.5S bracket	4S bracket	5S bracket	6S bracket
Ozone depletion	1.07	1.06	1.07	1.10	1.14	0.91	0.98	0.98	0.99	1.02	1.06
Global warming	1.09	1.08	1.09	1.13	1.18	0.88	0.97	0.96	0.98	1.02	1.07
Smog	1.09	1.08	1.09	1.14	1.19	0.88	0.97	0.97	0.98	1.02	1.07
Acidification	1.08	1.08	1.09	1.13	1.18	0.89	0.97	0.96	0.97	1.01	1.06
Eutrophication	1.08	1.08	1.09	1.13	1.18	0.88	0.97	0.96	0.97	1.01	1.06
Carcinogenics	1.10	1.09	1.11	1.16	1.21	0.89	0.99	0.98	0.99	1.04	1.10
Non-carcinogenics	1.11	1.10	1.12	1.17	1.23	0.89	1.00	0.99	1.01	1.06	1.12
Respiratory effects	1.08	1.08	1.09	1.13	1.18	0.88	0.97	0.96	0.97	1.01	1.06
Ecotoxicity	1.09	1.08	1.10	1.14	1.19	0.88	0.97	0.96	0.98	1.02	1.07
Fossil fuel depletion	1.09	1.08	1.09	1.13	1.18	0.89	0.98	0.97	0.98	1.03	1.08

**Table 41.** Scaling factors for MFI® system configurations (D-Series)

Impact category	MFI® D-Series system with D 16 ga rail						MFI® D-Series system with D 18 ga rail					
	2D bracket	3D bracket	3.5D bracket	4D bracket	5D bracket	6D bracket	2D bracket	3D bracket	3.5D bracket	4D bracket	5D bracket	6D bracket
Ozone depletion	1.25	1.32	1.29	1.32	1.35	1.39	1.08	1.15	1.13	1.15	1.19	1.22
Global warming	1.34	1.42	1.39	1.43	1.47	1.52	1.11	1.20	1.17	1.20	1.25	1.29
Smog	1.34	1.42	1.39	1.43	1.47	1.52	1.11	1.20	1.17	1.21	1.25	1.30
Acidification	1.33	1.42	1.39	1.42	1.46	1.51	1.11	1.19	1.16	1.20	1.24	1.29
Eutrophication	1.34	1.42	1.39	1.43	1.47	1.52	1.11	1.20	1.17	1.20	1.24	1.29
Carcinogenics	1.34	1.44	1.40	1.45	1.50	1.55	1.12	1.22	1.18	1.22	1.27	1.33
Non-carcinogenics	1.33	1.44	1.40	1.45	1.50	1.56	1.12	1.23	1.19	1.23	1.29	1.35
Respiratory effects	1.34	1.42	1.39	1.43	1.47	1.51	1.11	1.19	1.16	1.20	1.24	1.29
Ecotoxicity	1.35	1.44	1.40	1.44	1.49	1.54	1.12	1.20	1.17	1.21	1.26	1.31
Fossil fuel depletion	1.31	1.40	1.37	1.41	1.45	1.50	1.11	1.19	1.16	1.20	1.24	1.29

### 5.3.6. MFI® system – single bracket only

The PCR requires reporting the impacts for a single clip component, excluding any fasteners or rails. The cradle-to-gate life cycle impacts of a single representative bracket is included in Table 42. The extraction and upstream processing module contributes the largest share of impacts across all impact categories.

**Table 42.** Life cycle impact assessment results for a single bracket used in the MFI® system

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	kg CFC-11 eq	6.54E-09	6.04E-10	6.79E-10	<b>7.82E-09</b>
Global warming	kg CO2 eq	8.35E-01	4.12E-02	2.42E-02	<b>9.00E-01</b>
Smog	kg O3 eq	3.18E-02	9.87E-03	9.45E-04	<b>4.27E-02</b>
Acidification	kg SO2 eq	2.29E-03	3.06E-04	9.39E-05	<b>2.69E-03</b>
Eutrophication	kg N eq	3.08E-04	1.94E-05	7.94E-06	<b>3.36E-04</b>
Carcinogenics	CTUh	9.48E-09	1.45E-11	4.01E-11	<b>9.53E-09</b>
Non-carcinogenics	CTUh	6.71E-08	2.07E-09	7.68E-10	<b>6.99E-08</b>
Respiratory effects	kg PM2.5 eq	4.47E-04	1.96E-05	9.84E-06	<b>4.76E-04</b>
<b>Additional environmental information</b>					
Ecotoxicity	CTUe	1.39E+00	3.95E-02	4.29E-03	<b>1.43E+00</b>
Fossil fuel depletion	MJ surplus	7.47E-01	7.82E-02	5.67E-02	<b>8.82E-01</b>

### 5.3.7. MFI® system – rail only

The PCR requires reporting the impacts for a 12 linear inch length of continuous girt used in a cladding support system, excluding any fasteners. The cradle-to-gate life cycle impacts of 12 linear inches of the representative rail is included in Table 43. The extraction and upstream processing module contributes the largest share of impacts across all impact categories.

**Table 43.** Life cycle impact assessment results for 12 linear inches of rail used the MFI® system

Impact category	Unit	Extraction & upstream processing (A1)	Transport to factory (A2)	Manufacturing (A3)	Total (A1-A3)
Ozone depletion	kg CFC-11 eq	7.20E-09	1.21E-09	2.81E-09	<b>1.12E-08</b>
Global warming	kg CO2 eq	1.44E+00	8.26E-02	2.92E-02	<b>1.55E+00</b>
Smog	kg O3 eq	5.05E-02	2.01E-02	2.86E-03	<b>7.35E-02</b>
Acidification	kg SO2 eq	3.80E-03	6.23E-04	1.60E-04	<b>4.58E-03</b>
Eutrophication	kg N eq	5.44E-04	3.95E-05	1.96E-05	<b>6.03E-04</b>
Carcinogenics	CTUh	1.54E-08	2.86E-11	1.85E-10	<b>1.56E-08</b>
Non-carcinogenics	CTUh	8.77E-08	4.05E-09	5.53E-09	<b>9.73E-08</b>
Respiratory effects	kg PM2.5 eq	7.76E-04	3.95E-05	2.47E-05	<b>8.40E-04</b>
<b>Additional environmental information</b>					
Ecotoxicity	CTUe	2.63E+00	7.69E-02	2.89E-02	<b>2.75E+00</b>
Fossil fuel depletion	MJ surplus	9.51E-01	1.57E-01	3.17E-02	<b>1.14E+00</b>

#### 5.4. Sensitivity analysis

It is critical to understand the relative importance of different inputs in an LCA. Sensitivity analysis is essential to understand how variations in key inputs affect the results. It identifies which assumptions and data points significantly influence environmental impacts, assesses uncertainties, and improves model reliability.

The life cycle impact assessment results for each system type indicate that the A1 module is the primary driver of cradle-to-gate impacts. This is largely due to the amount of steel used in the system, which significantly influences the amount of upstream processing needed, such as steel extraction, slitting operations, and transportation to the KWS facility. Additionally, variations in steel quantity also affect the system's packaging requirements. To evaluate the variability in environmental impacts across different product configurations, a sensitivity analysis was conducted using cradle-to-gate results. While results were generated for all impact categories, only three are reported here for clarity and relevance: global warming potential, eutrophication, and fossil fuel depletion. These results were compared across multiple system configurations against a representative (baseline) configuration used in reporting.

The results, presented in Table 44 below, include all configurations of the CI® and HCI systems, with a selected subset assessed for other system types. The analysis showed that environmental impacts are highly sensitive to variations in steel mass between configurations. This sensitivity made it necessary to develop configuration-specific scaling factors within each product system type. As described in earlier sections, these factors enable the estimation of cradle-to-gate impacts for any given configuration by multiplying the representative product's impact results by the appropriate scaling factor. This approach ensures consistent, efficient, and accurate impact estimates across all product options.

**Table 44.** Sensitivity analysis using product configurations

Impact category	Global warming (kg CO <sub>2</sub> -eq emissions)		Eutrophication (kg N eq)		Fossil fuel depletion (MJ surplus)	
	(A1-A3) value	% change	(A1-A3) value	% change	(A1-A3) value	% change
<b>CI® system</b>						
Representative configuration (CI18*0.75)	3.64	N/A	1.42E-03	N/A	2.68	N/A
CI18*1.50	3.98	9.34%	1.55E-03	9.15%	2.93	9.33%
CI16*0.75	4.56	25.27%	1.78E-03	25.35%	3.35	25%
CI16*1.50	5.04	38.46%	1.99E-03	40.14%	3.59	33.96%
<b>HCI system</b>						
Representative configuration (HCI18*0.75)	4.92	N/A	1.91E-03	N/A	3.61	N/A
HCI16*0.75	6.22	26.50%	2.42E-03	26.55%	4.57	26.40%
HCI18*1.50	6.78	37.92%	2.64E-03	37.99%	4.98	37.78%
HCI16*1.50	8.27	68.08%	3.22E-03	68.20%	6.06	67.83%
<b>ThermaZee®</b>						
Representative configuration (TZ18*4)	5.48	N/A	2.08E-03	N/A	4.88	N/A
TZ18*1.5	5.26	-4.01%	1.99E-03	-4.21%	4.72	-3.37%
TZ16*2.5	7.38	34.67%	2.82E-03	35.62%	6.28	28.49%
TZ16*4.5	8.22	50.00%	3.15E-03	51.37%	6.89	41.08%
<b>PanelRail® &amp; RevealRail</b>						
Representative configuration (PR2*18*0.75)	4.03	N/A	1.57E-03	N/A	2.96	N/A
PR2*16*0.75	5.18	28.43%	2.01E-03	28.51%	3.80	28.29%
PR5*18*1.25	6.82	69.12%	2.65E-03	69.31%	5.00	68.80%
PR5*16*1.75	9.69	140.46%	3.77E-03	140.85%	7.11	139.81%
<b>MFI® system</b>						
Representative configuration (S16ga rail + 2S bracket)	4.00	N/A	1.54E-03	N/A	3.16	N/A
S16ga rail + 3Sbracket	4.34	8.51%	1.67E-03	8.32%	3.43	8.53%
D16ga rail + 2D bracket	5.35	33.63%	2.07E-03	33.91%	4.15	31.41%
D16ga rail + 6D bracket	6.08	51.87%	2.34E-03	51.74%	4.73	49.69%

## 5.5. Overview of relevant findings

This study assessed a multitude of inventory and environmental indicators. The primary finding for all KWS rainscreen cladding support system types, across all environmental indicators, was that raw material extraction and upstream processing (A1) is responsible for most of the cradle-to-gate impacts across all impact categories.

In that A1 module, the primary environmental impacts stem from the upstream manufacturing processes associated with steel production and processing. This includes the extraction and refinement of raw materials, as well as the slitting of steel sheets and coils at an upstream facility to achieve the required dimensions. These processes are energy-intensive and contribute significantly to the overall environmental footprint. Once prepared, the steel sheets and coils are shipped to the KWS facility for further processing and assembly.

The transportation module (A2) is also a contributor to several environmental impact categories. The primary sources of A2 impacts are the upstream transportation of raw and processed steel. This includes rail transport of steel coils and sheets to the slitting facility, followed by road transport of the slit coils and sheets to the KWS facility. Additionally, for the MFI® system where brackets are contract-manufactured, the extra transportation to and from the contract manufacturing facility further increases the environmental impacts. The energy consumption and emissions associated with these transportation processes significantly influence the overall cradle-to-gate environmental impacts.

The A3 module, encompassing the manufacturing operations at the facility, is primarily influenced by electricity usage. Across all environmental categories, the facility's electricity consumption in this stage contributes substantially to its impacts within the stage, emphasizing the role of energy management in reducing emissions.

## 5.6. Conclusion and recommendations

The goal of this study was to conduct a cradle-to-gate LCA on Knight Wall Systems' rainscreen cladding support systems so as to develop Transparency Reports [EPDs]™. The creation of these TRs will allow consumers in the building and construction industry to make better informed decisions about the environmental impacts associated with products they choose. Overall, this analysis highlights that the material extraction and upstream production module is the most significant contributor to the product's cradle-to-gate environmental impacts.

Raw material extraction and upstream processing are key areas where KWS can focus its efforts and exert influence. To reduce environmental impacts, KWS can explore alternative raw material sources that can minimize transportation distances or adopt more energy-efficient transportation methods. Partnering with logistics providers who operate low-emission or hybrid vehicles can also reduce impacts. Additionally, partnering with suppliers who employ sustainable manufacturing techniques like electric arc furnace steel production or integrate renewable energy into their processes could further reduce impacts from the supply chain.

It is recommended that KWS engage directly with its raw steel supplier and partner slitting facility to collect supplier-specific data on the production of steel sheets and coils. This data could provide valuable insights into potential areas for improvement within the raw materials module, helping KWS refine its sustainability strategies and reduce its overall environmental footprint.

As KWS can control its own manufacturing operations, there are opportunities to reduce cradle-to-gate environmental impacts. One key area of focus is on lowering electricity consumption during production processes, as this directly influences the facility's overall environmental footprint. Investing in on-site renewable energy sources, such as solar panels or wind turbines, can also reduce reliance on grid electricity and lower associated environmental impacts.

Additionally, an update to this LCA and the associated Transparency Reports [EPDs]™ would enable high-quality year-to-year comparisons and serve as the basis for a potential optimized EPD. A post-project review could provide opportunities for improving the data collection process in future years and for continuing to align with KWS's goals for sustainability.

## 6 REFERENCES

- [1] ISO 14025, “Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures”, ISO14025:2006
- [2] ISO 14040 ISO 14040:2006/Amd 1:2020, Environmental Management — Life Cycle Assessment — Principles and framework; and ISO 14044/Amd1:2017/Amd2:2020, “Environmental management - Life cycle assessment - Requirements and guidelines”, ISO14044:2006
- [3] ISO 21930, “Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services”, ISO 21930:2017.
- [4] Sustainable Minds, SM Transparency Report™ / EPD Framework Part A: LCA calculation rules and report requirements, version 2023, 2023.
- [5] Sustainable Minds, PCR Part B: Product group definition | Cladding Support Components and Systems, 2022.
- [6] Joep Meijer, Sustainable Minds SM2013 Methodology and Database, April 25, 2013. For a summary, see the Sustainable Minds single score page: <http://www.sustainableminds.com/showroom/shared/learn-single-score.html>
- [7] Bare, J. 2014. Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) TRACI version 2.1 User’s Guide. US EPA Office of Research and Development, Washington, DC, EPA/600/R-12/554, <http://nepis.epa.gov/Adobe/PDF/P100HN53.pdf>
- [8] Ryberg, M., Vieira, M.D.M., Zgola, M. et al. (2014). ‘Updated US and Canadian normalization factors for TRACI 2.1.’ Clean Technologies and Environmental Policy 16: 329. doi:10.1007/s10098-013-0629-z
- [9] Gloria, T. P., B. C. Lippiatt & J. Cooper (2007). ‘Life cycle impact assessment weights to support environmentally preferable purchasing in the United States.’ Environmental Science & Technology, 41(21), 7551-7557
- [10] “ACLCA Guidance to Calculating Non-LCIA Inventory Metrics in Accordance with ISO 21930:2017”, ACLCA PCR committee working group for ISO 21930 metric calculation guidance, May 2019.
- [11] Frischknecht R., Jungbluth N., et.al. (2003). Implementation of Life Cycle Impact Assessment Methods. Final report ecoinvent 2000, Swiss Centre for LCI. Duebendorf, CH, [www.ecoinvent.ch](http://www.ecoinvent.ch).
- [12] Heijungs R., Guinée J.B., Huppes G., Lankreijer R.M., Udo de Haes H.A., Wegener Sleeswijk A. Environmental Life Cycle Assessment of Products: Guide and Backgrounds. CML. Leiden University, Leiden, 1992.

## ACRONYMS

<b>ACLCA</b>	American Center for Life Cycle Assessment
<b>BOM</b>	Bill of materials
<b>ESL</b>	Estimated service life
<b>ISO</b>	International Standardization Organization
<b>LCA</b>	Life cycle assessment
<b>LCI</b>	Life cycle inventory
<b>LCIA</b>	Life cycle impact analysis
<b>PCR</b>	Product Category Rule document
<b>REC</b>	Renewable energy certificates
<b>RSL</b>	Reference service life
<b>TR</b>	Transparency Report [EPD] <sup>™</sup>

## GLOSSARY

For the purposes of this report, the terms and definitions given in ISO 14020, ISO 14025, the ISO 14040 series, and ISO 21930 apply. The most important ones are included here.

<b>Allocation</b>	Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems
<b>Close loop &amp; open loop</b>	A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials. An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties.
<b>Cradle to grave</b>	Addresses the environmental aspects and potential environmental impacts (e.g., use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition until the end of life
<b>Cradle to gate</b>	Addresses the environmental aspects and potential environmental impacts (e.g. use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition until the end of the production process ("gate of the factory"). It may also include transportation until use phase
<b>Declared unit</b>	Quantity of a product for use as a reference unit in an EPD based on one or more information modules
<b>Life cycle</b>	Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal
<b>Life cycle assessment - LCA</b>	Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle
<b>Life cycle impact assessment - LCIA</b>	Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product
<b>Life cycle inventory - LCI</b>	phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle
<b>Life cycle interpretation</b>	Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations

## APPENDIX

- Data\_collection\_form\_KWS\_cradletogate\_CI System.xlsx
- Data\_collection\_form\_KWS\_cradletogate\_HCI System.xlsx
- Data\_collection\_form\_KWS\_cradletogate\_PanelRail and RevealRail.xlsx
- Data\_collection\_form\_KWS\_cradletogate\_ThermaZee.xlsx
- Data\_collection\_form\_KWS\_cradletogate\_MFI System.xlsx
- LCI development\_KWS.xlsx
- LCIA\_Results\_KWS.xlsx