



John Beath Environmental, LLC
Striving to make something better every day

LIFE CYCLE ASSESSMENT OF HOT-ROLLED STRUCTURAL STEEL SECTIONS

Report # 298-001

Industry-average life cycle assessment of hot-rolled structural steel sections, commissioned by the American Institute of Steel Construction, according to ISO 14040, ISO 14044, ISO 21930, Smart EPD PCR Part A (v1.2, 2025) and Part B: Designated Steel Construction Products (v3.0, 2025).

Prepared for:

American Institute of Steel Construction (AISC)

130 East Randolph,
Suite 2000
Chicago, IL
60601

Report Issued: September 12, 2025



This report was prepared by John Beath Environmental, LLC. The company was founded in 2015 to provide sustainability and environmental consulting services. With staff dispersed across the US, the company provides consulting services with a focus on a unique combination of the life cycle perspective and deep knowledge of process modeling and regulatory obligations.

Prepared by:

Millie Aronson – Life Cycle Assessment & Sustainability Consultant
Sevda Alanya Rosenbaum, Ph.D. – Senior Consultant

Quality Assurance by:

Brandie Sebastian, LCACP – Senior LCA Advisor

Please send comments or suggestions about this document to our team:

148 S. Dowlen #86
Beaumont, TX 77707
1-888-777-4310 (U.S. Toll Free)

jbe@beath.us
www.beath.us

Legal Notice

The information contained in this document represents the current view of John Beath Environmental, LLC (JBE) on the issues discussed as of the date of publication. JBE cannot guarantee the accuracy of any information presented after the date of publication.

This document is for informational purposes only. JBE MAKES NO WARRANTIES, EXPRESS, IMPLIED OR STATUTORY, AS TO THE INFORMATION IN THIS DOCUMENT.

Complying with all applicable copyright laws is the responsibility of the user. Without limiting the rights under copyright, no part of this document may be reproduced, stored in or introduced into a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording, or otherwise), or for any purpose, without the express written permission of JBE.

2025 Rights Reserved

Table of Contents

| | | |
|------------|---|-----------|
| 1 | Goal of the Study | 9 |
| 2 | Scope of the Study | 10 |
| 2.1 | Product System | 10 |
| 2.1.1 | Production Processes..... | 11 |
| 2.1.2 | Product Composition..... | 11 |
| 2.2 | Declared Unit | 12 |
| 2.3 | System Boundaries | 12 |
| 2.3.1 | Time Coverage..... | 13 |
| 2.3.2 | Technology Coverage..... | 13 |
| 2.3.3 | Geographic Coverage..... | 14 |
| 2.4 | Cut-off Criteria | 14 |
| 2.5 | Allocation Procedures | 14 |
| 2.5.1 | Facility-level Allocation..... | 14 |
| 2.5.2 | Co-product Allocation..... | 14 |
| 2.5.3 | Steel Scrap Allocation..... | 15 |
| 2.5.4 | End-of-life Allocation..... | 15 |
| 2.6 | LCIA Methodology | 15 |
| 2.7 | Data Quality Requirements | 17 |
| 2.8 | Type of Document | 17 |
| 2.9 | Critical Review | 17 |
| 3 | Life Cycle Inventory Analysis | 18 |
| 3.1 | Data Collection and Modeling | 18 |
| 3.1.1 | Steel Mill Data Collection and Modeling..... | 18 |
| 3.1.2 | Use Stage..... | 22 |
| 3.1.3 | End-of-life Stage..... | 22 |
| 3.1.4 | Transport from Mills to Fabrication Data Collection and Modeling..... | 23 |
| 3.1.5 | Fabrication Data Collection and Modeling..... | 24 |
| 3.2 | Background Data | 28 |



3.3 Data Quality 28

 3.3.1 Requirements..... 28

 3.3.2 Gaps, Assumptions, and Limitations..... 30

3.4 EPD Data Specificity..... 31

4 LCIA Results..... 32

4.1 Industry-Average Hot-Rolled Structural Steel Sections Results (Excluding Fabrication)..... 32

 4.1.1 Hot-Rolled Structural Steel Sections Results Including Module D 34

4.2 Contribution Analysis Results 35

4.3 Steel Product Fabrication Results 37

4.4 Fabricated Hot-Rolled Structural Steel Sections Results 39

4.5 Statistics 41

4.6 Sensitivity Analysis 41

 4.6.1 Allocation Sensitivity 41

 4.6.2 Electricity Source Sensitivity..... 42

5 Interpretation 44

5.1 Identification of Relevant Findings 44

5.2 Conclusions, Limitations, and Recommendations..... 44

 5.2.1 Limitations 45

 5.2.2 Recommendations 45

References 46

Annex A: Unit Processes..... 48

Annex B: Background Data 53

Annex C: Renewable Energy Credits 66

Annex D [Critical Review Placeholder]..... 68



List of Figures

| | |
|---|----|
| Figure 1: Hot-rolled structural steel sections system boundaries, with fabrication..... | 13 |
| Figure 2: eGRID power mix split for each mill site..... | 19 |
| Figure 3: LCIA results of industry-average hot-rolled structural steel sections, in percent contribution | 33 |
| Figure 4: Contribution analysis results for production-weighted average hot-rolled structural sections (unfabricated)..... | 36 |
| Figure 5: Contribution analysis results for the U.S. average fabrication process | 38 |
| Figure 6: GWP results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections with average fabrication impacts..... | 40 |
| Figure 7: LCIA results of the baseline case (allocation to slag co-product) and scenario case (no co-product allocation), shown as percent of baseline..... | 42 |



List of Tables

| | |
|---|----|
| Table 1: Items included in and excluded from the system boundary..... | 12 |
| Table 2: Allocation ratios for slag and steel products at the mill sites..... | 15 |
| Table 3: Impact Categories and ISO 21930 Indicators | 16 |
| Table 4: Transport data for gap-filling..... | 18 |
| Table 5: eGRID and ecoinvent/NERC subregions for each mill site..... | 19 |
| Table 6: Summary LCI for the production-weighted average EAF steelmaking unit process..... | 21 |
| Table 7: Summary LCI for the production-weighted average section rolling unit process..... | 22 |
| Table 8: Reference Service Life..... | 22 |
| Table 9: End of Life (C1-C4) | 23 |
| Table 10: A2 unit process for transporting 1.0771 metric tons of hot-rolled structural steel from the mills to the fabricators..... | 24 |
| Table 11: Electrode composition by type | 25 |
| Table 12: Welding flux composition | 25 |
| Table 13: U.S. states and mapped NERC subregions based on fabricator geography..... | 26 |
| Table 14: Percent of electricity share based on fabrication throughput by NERC subregion | 27 |
| Table 15: Unit process for average, 10th percentile, and 90th percentile for 1 metric ton of fabricated hot-rolled structural steel sections..... | 27 |
| Table 16: Data quality requirements and evaluation of data quality | 29 |
| Table 17: Data gaps, assumptions, and limitations | 30 |
| Table 18: LCIA results for 1 metric ton of industry-average hot-rolled structural steel sections..... | 33 |
| Table 19: Resource use results for 1 metric ton of industry-average hot-rolled structural steel sections | 33 |
| Table 20: Waste and output results for 1 metric ton of industry-average hot-rolled structural steel sections | 34 |
| Table 21: Carbon emissions and removals results for 1 metric ton of industry-average hot-rolled structural steel sections..... | 34 |
| Table 22: Reuse, Recover, and/or Recycling Potentials (D), Relevant Scenario Information..... | 35 |
| Table 23: LCIA results for 1 metric ton of industry-average hot-rolled structural steel sections including Module D..... | 35 |
| Table 24: LCIA results for the industry-average structural steel fabrication process to produce 1 MT of fabricated steel products..... | 37 |
| Table 25: Resource use results for 1 metric ton of industry-average structural steel fabrication..... | 37 |
| Table 26: Waste and output results for 1 metric ton of industry-average structural steel fabrication | 37 |
| Table 27: Carbon emissions and removals results for 1 metric ton of industry-average structural steel fabrication..... | 37 |
| Table 28: LCIA results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections ... | 39 |
| Table 29: Resource use results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections | 39 |



Table 30: Waste and output results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections 39

Table 31: Carbon emissions and removals results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections 39

Table 32: GWP results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections with average, 90th percentile, and 10th percentile fabrication impacts 41

Table 33: Statistical metrics for 1 metric ton of hot-rolled structural steel sections (A1-A3) across all facilities 41

Table 34: LCIA results for 1 metric ton of fabricated hot-rolled structural steel sections, with no burden assigned to slag co-product 41

Table 35: LCIA results showing allocation burden assigned to slag 42

Table 36: LCIA results for 1 metric ton of industry-average hot-rolled structural steel sections- without RECs 43

Table 37: Complete unit process for 1 metric ton of the industry-average EAF process..... 48

Table 38: Complete unit process for 1 metric ton of the industry-average section rolling process..... 51

Table 39: Key process data source reporting, from Smart EPD’s Part B PCR, Table D-1..... 53

Table 40: A1 background data - EAF (ecoinvent v3.10, cutoff unit process models)..... 55

Table 41: A1 background data – Section Rolling (ecoinvent v3.10, cutoff unit process models) 59

Table 42: A2 background data (ecoinvent v3.10, cutoff unit process models)..... 62

Table 43: A3 background data (ecoinvent v3.10, cutoff unit process models)..... 62

Table 44: Modules C1-C4 background data (ecoinvent v3.10, cutoff unit process models) 65

Table 45: Renewable Electricity Details..... 66

List of Abbreviations

| | | | |
|--------------------|---|-------------------|---|
| ADP _f | Abiotic Depletion Potential, Fossil Resources | MER | Materials for Energy Recovery |
| AISC | American Institute of Steel Construction | MJ | Megajoules |
| AISI | American Iron and Steel Institute | MR | Materials for Recycling |
| AP | Acidification Potential | MT | Metric Ton |
| CFC | Chlorofluorocarbon | N | Nitrogen |
| CO ₂ | Carbon Dioxide | NERC | North American Electric Reliability Corporation |
| CO ₂ eq | Carbon Dioxide Equivalent | NHWD | Non-Hazardous Waste Disposed |
| CRU | Components for Re-Use | NRPR _E | Non-Renewable Primary Resources – Energy |
| EAF | Electric Arc Furnace | NRPR _M | Non-Renewable Primary Resources – Material |
| EE | Recovered Energy Exported | NRSF | Non-Renewable Secondary Fuels |
| eGRID | Emissions & Generation Resource Integrated Database | O ₃ | Ozone |
| EP | Eutrophication Potential | ODP | Ozone Depletion Potential |
| EPD | Environmental Product Declaration | PCR | Product Category Rule |
| FW | Use of Net Freshwater Resources | PED | Primary Energy Demand |
| GHG | Greenhouse Gas | RE | Recovered Energy |
| GLO | Global | RoW | Rest of World |
| GWP | Global Warming Potential | RSRM | Rolling Mill |
| HLRW | High-Level Radioactive Waste | RPR _E | Renewable Primary Resources – Energy |
| HWD | Hazardous Waste Disposed | RPR _M | Renewable Primary Resources – Material |
| ILLRW | Intermediate and Low-Level Radioactive Waste | RSF | Renewable Secondary Fuels |
| IPCC | Intergovernmental Panel on Climate Change | SFP | Smog Formation Potential |
| ISO | International Standards Organization | SM | Secondary Materials |
| JBE | John Beath Environmental, LLC | SO ₂ | Sulfur Dioxide |
| LCA | Life Cycle Assessment | TRACI | Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts |
| LCI | Life Cycle Inventory | VOC | Volatile Organic Compound |
| LCIA | Life Cycle Impact Assessment | | |
| m ³ | Cubic Meters | | |

1 Goal of the Study

The American Institute of Steel Construction (AISC) is a not-for-profit technical institute and trade association in the U.S. serving the structural steel community. The National Steel Bridge Alliance (NSBA), a division of AISC, is a national, not-for-profit organization dedicated to the advancement of steel bridge design and construction. The NSBA functions as the voice of the bridge fabricators and steel mills while also partnering with the bridge design and construction community. AISC and NSBA are co-commissioners of this study, though referenced together as “AISC” throughout this report.

AISC is interested in quantifying potential environmental impacts of its fabricator and hot-rolled structural steel sections producer member’s products and processes through a cradle-to-mill-gate with options (A1–A3, B1–B7, C1–C4) life cycle assessment (LCA), and in communicating potential environmental impacts to customers through an updated industry-average environmental product declaration (EPD). LCA is used to evaluate potential environmental impacts and various resource, energy, water, and waste indicators for a product over its life cycle.

AISC commissioned John Beath Environmental, LLC (JBE) to conduct an industry-average LCA of U.S.-produced hot-rolled structural steel sections, including a refresh of the U.S.-average transportation to fabricator and fabrication process impacts. The study scope includes the procurement of raw materials and fuels, steel mill operations, product use, and end-of-life. The study was conducted according to the requirements of ISO 14040:2006 (ISO, 2006a), ISO 14044:2006 (ISO, 2006b), ISO 21930 (ISO, 2017), Product Category Rule (PCR) Part A: Product Category Rules for Building and Construction Products and Services (Smart EPD, 2025a), and PCR Part B: Product Category Rules for Designated Steel Construction Products, Version 3 (Smart EPD, 2025b).

The intended application for this study is to understand improvement, identify hotspots, and share updated potential environmental impacts of the U.S. industry’s hot-rolled structural steel sections with customers and potential future customers (business-to-business communications), and the industry at large. The primary audience for this study is internal stakeholders at AISC as well as broad-ranging external stakeholders.

This study report has undergone critical review by an independent expert in accordance with ISO 14040:2006, ISO 14044:2006, ISO 14025:2006, ISO 21930:2017, and the applicable PCRs to ensure accuracy and quality, and adherence to the specified standards prior to EPD development.

2 Scope of the Study

2.1 Product System

Hot-rolled structural steel sections are typically used in construction applications in buildings, bridges, and industrial projects. This industry-average, cradle-to-mill-gate with options LCA study represents the production-weighted average of hot-rolled structural steel sections produced by mills in the U.S. in 2023 and subsequently fabricated at facilities throughout the U.S. The mills and fabricators participating in this study are members of AISC.

While a variety of steel products may be produced via hot-rolling, in the context of structural steel construction, this study's product scope is limited to the following definition.

Hot-rolled structural steel sections are:

- *W-, S-, C-, and MC- shapes, angles, and*
- *Produced at a mill whose primary output is heavy structural sections intended for subsequent fabrication and installation in buildings, bridges, and other structural applications*

Hot-rolled structural steel sections specifically exclude:

- *Products that do not meet the definition of structural steel per AISC's Code of Standard Practice for Steel Buildings and Bridges (ANSI/AISC 303-22), such as H-piles, sheet pile, railroad rail, and crane rail*
- *Products originating from a "Bar Mill", such as rebar, MBQ, SBQ, rod, and wire*
- *"Junior" sections, such as those under 8 inches in depth*
- *Miscellaneous M- shapes*

The mill sites included in this study, representing 100% of U.S. hot-rolled structural steel sections production in the study year, are:

- Steel Dynamics, Inc. (SDI) Columbia City, IN
- Gerdau Petersburg, VA
- Gerdau Midlothian, TX
- Gerdau Cartersville, GA
- Nucor Yamato, AR
- Nucor Berkeley, SC

Also included in the study were 80 fabricator sites out of AISC's approximately 1,000 fabricator members. The participating companies represent approximately 19% of the total steel tonnage fabricated by AISC's membership, which makes up approximately 75% of the total fabrication tonnage in the U.S. These facilities provided data for the AISC 2021 EPD background report (Sphera, 2021), representing 2019-2020 production. The average, 10th percentile, and 90th percentile primary data aggregated for that study was updated with background data representative for 2023 in this study.

Retroactive participation in this study and the resultant industry-average EPD will be determined by AISC and Smart EPD in accordance with Smart EPD Part B Section 5.3.2.2.2.

Hot-rolled structural steel sections fall under CSI and UNSPSC codes:

- CSI 05 12 00 Structural Steel Framing

- CSI 05 12 13 Architecturally-Exposed Structural Steel Framing
- CSI 05 12 23 Structural Steel for Buildings
- UNSPSC 30103618 – Steel framework

Additional information on products produced by AISC’s members are provided on the AISC website: <https://www.aisc.org/>.

2.1.1 Production Processes

Hot-rolled structural steel sections in the U.S. are produced exclusively by electric arc furnace (EAF) steel mills. Feedstock materials, including steel scrap with smaller amounts of pig iron, direct-reduced iron (DRI), and alloying elements, arrive at the mills via ship, barge, rail, and truck. Steel scrap, pig iron, and DRI are charged into EAFs where they are melted using electric current applied through high-carbon electrodes. Lime, charge carbon, and process-related gases like oxygen are added during the melting process to remove impurities from the steel and achieve the desired steel grade. Slag is formed as a co-product during the EAF process. Molten steel is transferred to a ladle metallurgy furnace (LMF) where more additives and alloy materials are added to achieve the desired composition of the final product. The steel then enters the continuous casting process where the first solid form of steel (termed raw steel or crude steel) is produced in long shapes termed “blooms” or “billets”. Steel scrap generated during this process is “internal scrap” and is returned to the EAF for re-melting.

Typically, at the same mill facility, but not always, blooms/billets are transferred to the hot-rolling mill where they are reheated using primarily natural gas and rolled into a variety of structural shapes. Scrap generated downstream from the casting process within a facility, such as at the rolling mill, is termed “home scrap” and is returned to the EAF for re-melting. Hot-rolled structural steel sections are cooled, cut to standard lengths, and then transported off-site for use or further processing.

Prior to installation, hot-rolled structural steel sections commonly undergo a scenario-specific fabrication process. This process entails inspection, material handling, cutting, drilling, fit-up, welding, and bolting; all according to the AISC Code of Standard Practice for Steel Buildings and Bridges (ANSI/AISC 303-22, 2022). In addition to the steel itself, inputs to fabrication include relatively small amounts of process materials, such as lubricants, gases, electrodes, and welding fluxes. Some facilities also conduct surface preparation using mechanical processes or compressed air blasting in order to clean the surface and prepare it for coating. Surface preparation for the application of coatings, the coatings themselves, and galvanization are not included in the scope of this study. Scrap generated during the fabrication processes is considered manufacturing scrap and is returned to steel mills as a pre-consumer external scrap input.

2.1.2 Product Composition

The hot-rolled structural steel sections analyzed in this study are made primarily of recycled steel scrap, with some mills additionally utilizing varying percentages of virgin iron inputs, including pig iron and DRI, as well as up to 2% alloying elements. The production-weighted average recycled content of the product is 92.0%. The share of pre- and post-consumer recycled content was not calculated due to data availability. Average virgin iron inputs were 6.5% and average alloying elements were 1.5% of the total product mass. The product has a typical density of approximately 7,850 kg/m³.

The products do not contain any hazardous substances according to the Resource Conservation and Recovery Act (RCRA), Subtitle 3. The products do not release dangerous substances to the environment, including indoor air emissions, gamma or ionizing radiation, or chemicals released to air or leached to water and soil. Therefore, no substances required to be reported as hazardous are associated with the production of this product.

2.2 Declared Unit

The declared unit for this study is **one (1) metric ton (1,000 kg) of hot-rolled structural steel sections**.

The functional unit of an LCA is the quantification of a product's performance characteristics and is the reference unit for which all results are presented. As this study has a cradle-to-mill-gate with options scope that excludes the distribution and construction phase (Modules A4 and A5)¹, for consistency with the governing PCR, a declared unit is used instead of a functional unit. For the purposes of reporting the use phase (Module B), the defined Reference Service Life is 75 years.

Please note that comparisons of environmental impact results on a mass basis alone are insufficient and should consider the technical performance of the product to establish comparisons.

2.3 System Boundaries

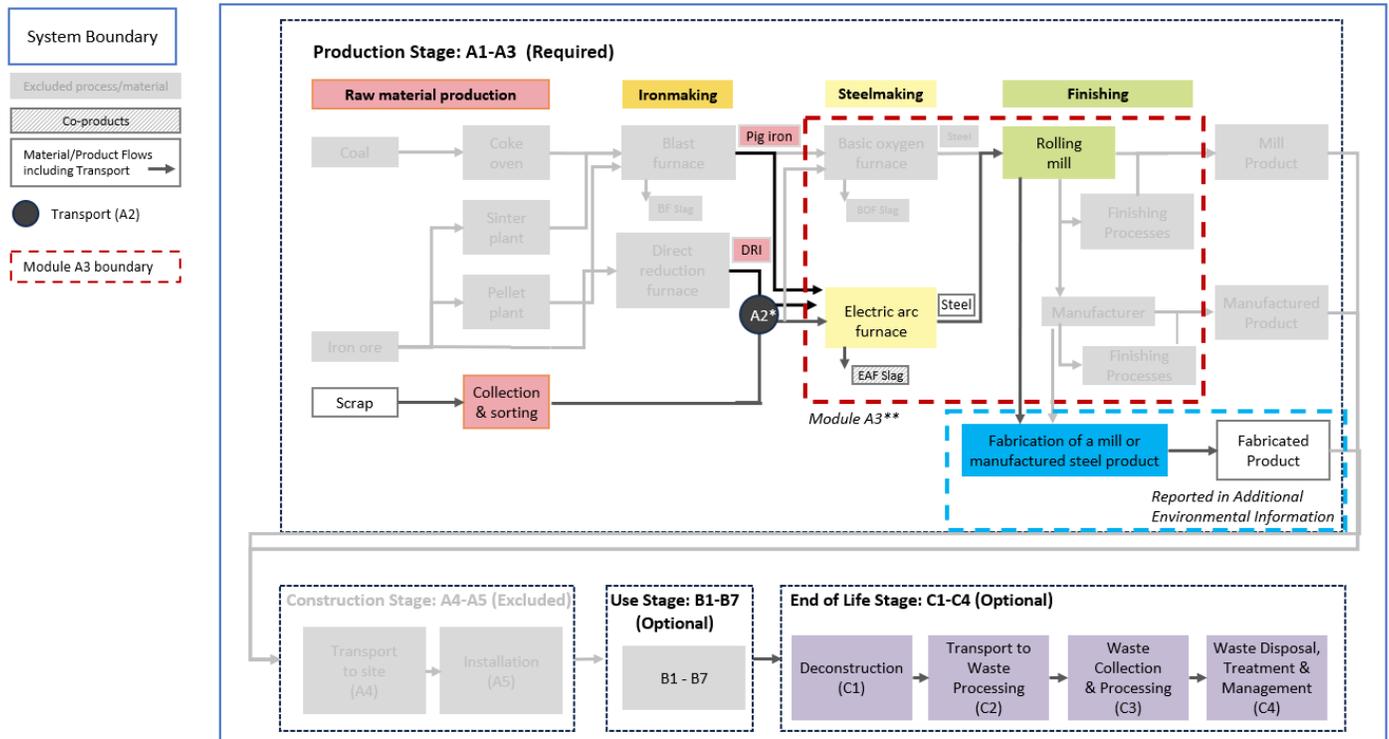
The system boundary in an LCA defines which unit processes are considered in the modeled system. Unit processes are one or several operations in a manufacturing system. Processes are organized into modules per ISO 21930:2017 and the governing PCR. This analysis is based on a cradle-to-mill-gate with options scope (modules A1-A3, B1-B7, C1-C4). The specific processes and life cycle stages included, and those that are excluded, are detailed in Table 1 and in Figure 1. The intent of this study is to capture all known and material product-specific impacts from raw material extraction to mill gate, the subsequent scenario of fabrication, and all associated releases to the environment.

Table 1: Items included in and excluded from the system boundary

| Included | Excluded |
|---|--|
| <ul style="list-style-type: none"> • Mill processes, including procurement of scrap, virgin inputs (e.g. pig iron and scrap), alloying elements, and other process materials, utilities, and all associated production and inbound transport. Additionally, waste treatment processes and outbound transport. The slag co-product is also included at this stage. • Transport of the hot-rolled structural sections to the fabricators • Fabrication, including material requirements (e.g. electrodes), as well as other process materials and utilities, and the production and inbound transport of all of these. Additionally, waste treatment processes and outbound transport of these. • Use phase of the product • End-of-life stages, including demolition, transport, waste processing, and disposal | <ul style="list-style-type: none"> • Manufacturing equipment maintenance • Capital equipment, infrastructure, and maintenance • Human labor and employee commute • Optional life cycle stages: product distribution (A4) and installation (A5) |

Capital goods and infrastructure have been excluded per ISO 21930. Future PCR updates may consider capital goods and infrastructure when lifetimes or standardized methods of computing lifetimes for the industry become available, as well as consensus-based depreciation methods to allocate the burden of capital goods over their service period.

¹ Modules A4 (distribution) and A5 (installation) have been excluded due to the current lack of robust data to model these stages.



Source: Smart EPD Part B PCR (v3, 2025)

Notes: Each unit process includes resource inputs (fuels, electricity, water, materials, etc.) and emissions to air/land/water, wastes and co-products, if relevant.

* A2 transportation is represented by any black arrow that crosses A1 / A3 boundary.

** Processes inside the red dashed line are in module A3 and include specific data. Processes outside of the dashed red line indicate processes in module A1.

Figure 1: Hot-rolled structural steel sections system boundaries, with fabrication

2.3.1 Time Coverage

This study is intended to represent the 2023 calendar year. Primary data was collected for steel mill facilities for 12 consecutive months of production during 2023, apart from one mill providing data for July 2023 to June 2024.

The data from fabrication facilities represents primary data collected for the 2019 and 2020 calendar years and used in AISC’s 2021 industry-average EPD. The production-weighted fabrication life cycle inventory (LCI) data was updated for this study in two ways to improve time coverage. First, the fabrication tonnage for each state was provided by AISC for the 2023 calendar year, which was used to update the mix of region-specific electricity datasets paired with the inventory. Second, all background datasets were updated to the ecoinvent database v3.10, representing the 2023 calendar year. See Section 3.1.3 for additional details.

2.3.2 Technology Coverage

This study aims to represent the industry-average of manufacturing technologies used by AISC’s members to manufacture hot-rolled structural steel sections in the U.S., including a fabrication scenario. Hot-rolled structural steel sections are produced exclusively by EAF steelmaking processes in the U.S., and 100% of production is represented in this study. In addition, a total of 80 fabrication facilities are included in the study utilizing a representative mix of current fabrication techniques for the U.S.

2.3.3 Geographic Coverage

This study aims to represent the industry-average of hot-rolled structural steel sections produced and fabricated in the U.S. The study includes 100% of hot-rolled structural steel sections production in the U.S., as well as 80 fabricator facilities dispersed throughout the U.S. The electricity mix for the U.S.-fabricator population was modeled in this study.

2.4 Cut-off Criteria

No cut-off criteria were defined for this analysis. All known energy and material flow data were included in accordance with the system boundary. Proxy data were used as needed in the model to capture all considered life cycle impacts, as is detailed in Annex A.

2.5 Allocation Procedures

2.5.1 Facility-level Allocation

Data from the mills was requested for two distinct unit processes: 1) EAF steelmaking (cradle-to-crude steel), and 2) section rolling (crude steel to hot-rolled sections). The majority of data was provided by the facilities separately for the two unit processes. Where data was provided on a facility-wide basis, including some on-site transportation fuels, non-CO₂ air emissions, and wastes, allocation was performed to assign each item into the unit processes at a ratio of 50:50 before accounting for the share of in-scope production.

Additionally, data was requested from each mill on the production of products that were deemed out-of-scope. In-scope products were defined for this study as described in Section 2.1. For facilities where out-of-scope products were also produced, impacts were scaled to the share of in-scope products based on production masses.

2.5.2 Co-product Allocation

A process, sub-system, or system may produce co-products in excess of the necessary reference flow or intermediate product. Such co-products leave the system to be used beneficially in other systems and may carry a portion of the burden of their production system. To allocate burden in a meaningful way between co-products, allocation procedures are needed.

During the EAF process at the mills, slag is produced via a joint co-production process per ISO 21930:2017 along with steel blooms/billets. EAF slag is sold directly from the mills for beneficial use as an aggregate among other applications. In accordance with the governing PCR, physical partitioning was used to allocate a share of each of the inputs and outputs at the EAF to the steel and the slag based on the energy demand required to form each co-product and other physical relationships. The ratios applied to each flow were sourced from the World Steel Association and EUROFER's 2014 slag LCI methodology report (The World Steel Association, 2014), and are summarized in Table 2 below. These values were entered as causal allocation factors in openLCA.

Table 2: Allocation ratios for slag and steel products at the mill sites

| Item Category | Allocation Share to Slag | Allocation Share to Steel |
|--|--------------------------|---------------------------|
| Scrap | N/A | N/A |
| Pig Iron | 0.0091 | 0.9909 |
| DRI | 0.04 | 0.96 |
| Alloying Elements | 0 | 1 |
| Fluorspar | 1 | 0 |
| Ancillary Materials (e.g., Refractories, Electrodes) | 0.14 | 0.86 |
| Oxygen, Argon, Nitrogen Gases | 0 | 1 |
| Energy Inputs | 0.14 | 0.86 |
| Water Inputs | 0.14 | 0.86 |
| Air Emissions | 0.14 | 0.86 |
| Wastes | 0 | 1 |

Other materials recovered for recycling at the mills, such as mill scale and EAF dust, were modeled with the cut-off approach (polluter pays principle), whereby the burden of the recycling processes was not included, however the burden of transporting the recyclable wastes to the waste treatment location was included. A sensitivity was conducted on co-product allocation in Section 4.6.

No co-product allocation was required for the fabrication process, as no co-products are produced. Furthermore, background data for the study used a cut-off approach for co-product allocation.

2.5.3 Steel Scrap Allocation

The largest raw material input for hot-rolled structural steel sections production is external steel scrap. Relatively small amounts of internal scrap, which is generated at the EAF process and fed back into the EAF, and home scrap, which is scrap generated downstream of the castor within a steelmaking facility, are also consumed as inputs. In accordance with the governing PCR and ISO 21930's "polluter pays principle", external steel scrap was assigned no upstream burden from its production. The inbound transportation of scrap and any on-site mobile fuels or energy consumption necessary to sort and move scrap at the mills were included. Both internal and home scrap were modeled as secondary materials receiving no burden as they stay within the facility's bounds and impacts associated with their production and processing were captured in the site-wide inventories.

2.5.4 End-of-life Allocation

Hot-rolled structural steel sections are typically recycled at the end-of-life. The average disposal pathways provided in Table 3 of the Part A PCR were used in this study. It is assumed that 97% of the structural steel is recycled, while the remaining 3% is landfilled. Background data for the study used a cut-off approach for end-of-life allocation.

2.6 LCIA Methodology

The impact assessment categories and other metrics used in the assessment are based on the requirements of the PCR and are shown below. The impact categories are calculated using globally accepted methods: Intergovernmental Panel on Climate Change (IPCC), Sixth Assessment Report (AR6) using Environmental Footprint (EF) reference package version 3.1 (European Commission, 2022), Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) (Bare, 2011), version 2.2, and Institute of Environmental Sciences (CML) in the Netherlands, version 4.7. This study is intended to quantify global warming potential (GWP-100, GWP-fossil, GWP-biogenic, and GWP-luluc), ozone depletion potential (ODP), acidification potential (AP), eutrophication potential (EP), smog formation potential (SFP), and abiotic depletion of fossil fuel resources (ADP_f) of AISC's industry-average hot-rolled structural steel sections. These

six 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.

In accordance with the PCR and ISO 21930, 17 inventory metrics were also calculated, as shown in Table 3 below. The inventory metrics were calculated using the recommendation of ACLCA 21930 guidance document (ACLCA, 2018). The characterization models (IPCC AR6, TRACI 2.2, and CML v4.7) and characterization factors are identified according to the requirements of the PCR Part A.

Table 3: Impact Categories and ISO 21930 Indicators

| Abbreviation | Indicator | Unit |
|--------------------------------|---|------------------------|
| LCIA Impact Categories | | |
| GWP-total | Global warming potential - Total | kg CO ₂ -eq |
| GWP-fossil | Global warming potential - Fossil | kg CO ₂ -eq |
| GWP-biogenic | Global warming potential - Biogenic | kg CO ₂ -eq |
| GWP-luluc | Global warming potential – Land Use and Land Use Change | kg CO ₂ -eq |
| ODP | Ozone depletion potential | kg CFC 11-eq |
| AP | Acidification potential | kg SO ₂ -eq |
| EP | Eutrophication potential | kg N-eq |
| SFP | Smog formation potential | kg O ₃ -eq |
| ADP _f | Abiotic resource depletion potential of non-renewable (fossil) energy resources | MJ, LHV |
| Resource Use | | |
| RPR _E | Renewable primary resources used as energy carrier (fuel) | MJ, LHV |
| RPR _M | Renewable primary resources with energy content used as material | MJ, LHV |
| NRPR _E | Non-renewable primary resources used as an energy carrier (fuel) | MJ, LHV |
| NRPR _M | Non-renewable primary resources with energy content used as material | MJ, LHV |
| SM | Secondary materials | kg |
| RSF | Renewable secondary fuels | MJ, LHV |
| NRSF | Non-renewable secondary fuels | MJ, LHV |
| RE | Recovered energy | MJ, LHV |
| FW | Use of net freshwater resources | m ³ |
| Output Flows and Wastes | | |
| HWD | Hazardous waste disposed | kg |
| NHWD | Non-hazardous waste disposed | kg |
| HLRW | High-level radioactive waste, conditioned, to final repository | kg |
| ILLRW | Intermediate- and low-level radioactive waste, conditioned, to final repository | kg |
| CRU | Components for re-use | kg |
| MR | Materials for recycling | kg |
| MER | Materials for energy recovery | kg |
| EE | Recovered energy exported from the product system | MJ, LHV |

The product does not contain significant amounts of biogenic carbon, nor does the manufacturing process use biomass or biofuels as a major energy source. Some mills used relatively small amounts of pig iron produced from biochar; however, this was excluded from the study due to data limitations with all pig iron inputs conservatively modeled as conventionally produced pig iron. Results for carbon emissions and removals (PCR Part A, Section 9.5.2.3) are not relevant to this LCA and EPD and, therefore, are not reported. Furthermore, the production and fabrication of hot-rolled structural steel sections does not involve calcining or carbonation processes.

This study does not address other environmental indicators or impact categories, nor does it consider social impacts, land use, biodiversity, human health or ecotoxicity, or local impacts such as noise.

2.7 Data Quality Requirements

The key requirement for data quality is that data be as accurate and representative as possible. Data quality requirements are based on the ISO 14040:2006 and ISO 14044:2006 standards and include time-related, geographical, technological, precision, completeness, representativeness, consistency, reproducibility, sources of data, and uncertainty criteria. To fulfill these requirements and to ensure reliable results, primary data in combination with representative secondary literature, and consistent background LCI data from ecoinvent v3.10 (Wernet, et al., 2016) and other sources were used. The data quality assessment is described in Section 3.3 and all background datasets are identified in Annex B.

2.8 Type of Document

This report is written to conform to the requirements of ISO 14040:2006, ISO 14044:2006, ISO 21930:2017, Smart EPD's PCR Part A: Product Category Rules and Report Requirements, and PCR Part B: Designated Steel Construction Products. As such, this document aims to report the results and conclusions of the LCA completely and accurately, without bias to the intended audience. The results, data, methods, assumptions, and limitations are presented in a transparent manner with the intention to provide sufficient detail to allow the reader to comprehend the complexities and trade-offs inherent to the LCA. The report aims to be used in a manner consistent with the goals of the study.

2.9 Critical Review

This study has been subjected to a critical review by Rifat Karim, an independent expert under the direction of Smart EPD. This review was conducted to ensure consistency between the completed LCA and the requirements of ISO 14040:2006, ISO 14044:2006, ISO 21930:2017, and the relevant PCRs.

3 Life Cycle Inventory Analysis

3.1 Data Collection and Modeling

The following sections describe data collection processes and modeling approaches for the study. The study utilized openLCA v2.4 to model primary data paired with data from the ecoinvent v3.10 and the U.S. Life Cycle Inventory Database (USLCI) version 1.2024-06.0 (Federal LCA Commons, 2024) secondary databases.

3.1.1 Steel Mill Data Collection and Modeling

As described in Section 2.5.1, primary data was collected from six steel mills for two unit processes: 1) EAF steelmaking, and 2) section rolling. One year of production data was provided representing the 2023 calendar year. Allocation procedures were performed as-needed to assign facility data to the EAF and section rolling stages and also to scale to the share of in-scope products, as described in Section 2.5.1. Mills provided all virgin iron and recycled steel inputs, alloy materials, process materials, packaging, utilities and energy requirements, waste and waste fates, and emissions.

As part of the rigorous QA process, primary data was checked for mass balance, water balance, and completeness. Once all site data was received, efforts were made to cross-check key raw material, energy, and emissions data provided from each mill, identify gaps and outliers, and seek clarifications and data from the mills or gap-fill with average data from the other sites.

Most sites provided complete inbound transportation distances and modes. One site provided only scrap transportation distances (comprising the majority of in-bound transportation) and requested that JBE use transportation modes and distances from another site at their company as proxy data. Where needed, gap-filling took place whereby the distances and modes shown in Table 4 were applied based on average data provided by raw material type for all sites unless otherwise specified.

Table 4: Transport data for gap-filling

| Item Category | Distance (km), Mode |
|------------------------|-------------------------|
| Alloying Elements | 1,500 truck; 6,000 ship |
| All Other Inputs* | 250 truck; 1,000 rail |
| Waste Flows | 50 truck |
| Material for Recycling | 50 truck |

* Aligns with AISI's 2017 industry-average LCI data study assumptions (American Iron and Steel Institute, 2020).

Where sites did not provide air emissions data that included fuel combustion at the mill sites, combustion datasets for natural gas (used as a fuel) which account for the impact of producing and burning the fuel were used. For all sites, fuels used for on-site transportation and equipment, including propane, gasoline, and diesel, were modeled with fuel production and consumption datasets.

Datasets were mapped to all inputs and outputs primarily in ecoinvent v3.10. To align with the Smart EPD PCR requirements, transportation datasets were modeled using the USLCI database, with non-elementary flows matched to ecoinvent datasets in openLCA. See Annex B for a complete list of background datasets used in this study. Long-haul and short-haul transportation distances were used to model inbound and outbound transport where relevant. For A2, short-haul transport (local trucks, <200 miles) is assumed to



return empty, in line with SmartEPD PCR Part A requirements. The USLCI database assumes a 35% backhaul rate, therefore, the existing dataset was modified by multiplying emissions by 1.48 to account for the empty return. For long-haul transport (>200 miles), it is assumed that bulk carriers do not typically return empty. For the long-haul transportation calculations, the USLCI dataset for long-haul transport was used without modification, consistent with PCR guidance.

For purchased electricity datasets, each mill site was designated an Emissions & Generation Resource Integrated Database (eGRID) subregion based on its location in the U.S. (United States Environment Protection Agency, 2025). The percentage of each type of power used in the subregion was sourced from the most recent eGRID data, representing calendar year 2022. Each power type was then mapped to ecoinvent datasets for electricity production by electricity source type for that subregion. If a power type did not have a subregion-specific dataset, the next closest geographic region was chosen. An openLCA process was generated for each mill using the subregion-specific datasets for each power type and percentage contribution. Table 5 shows the mapping of mill sites to eGRID subregions and ecoinvent dataset subregions. Figure 2 shows the power mix types and percentage split for each mill location.

Table 5: eGRID and ecoinvent/NERC subregions for each mill site

| Mill Site | eGRID Subregion | ecoinvent Subregion |
|---------------------|-----------------|---------------------|
| SDI | RFCW | RF |
| Gerdau Petersburg | SRVC | SERC |
| Gerdau Midlothian | SRMV | SERC |
| Gerdau Cartersville | SRSO | SERC |
| Nucor Yamato | SRVC | SERC |
| Nucor Berkeley | ERCT | TERC |

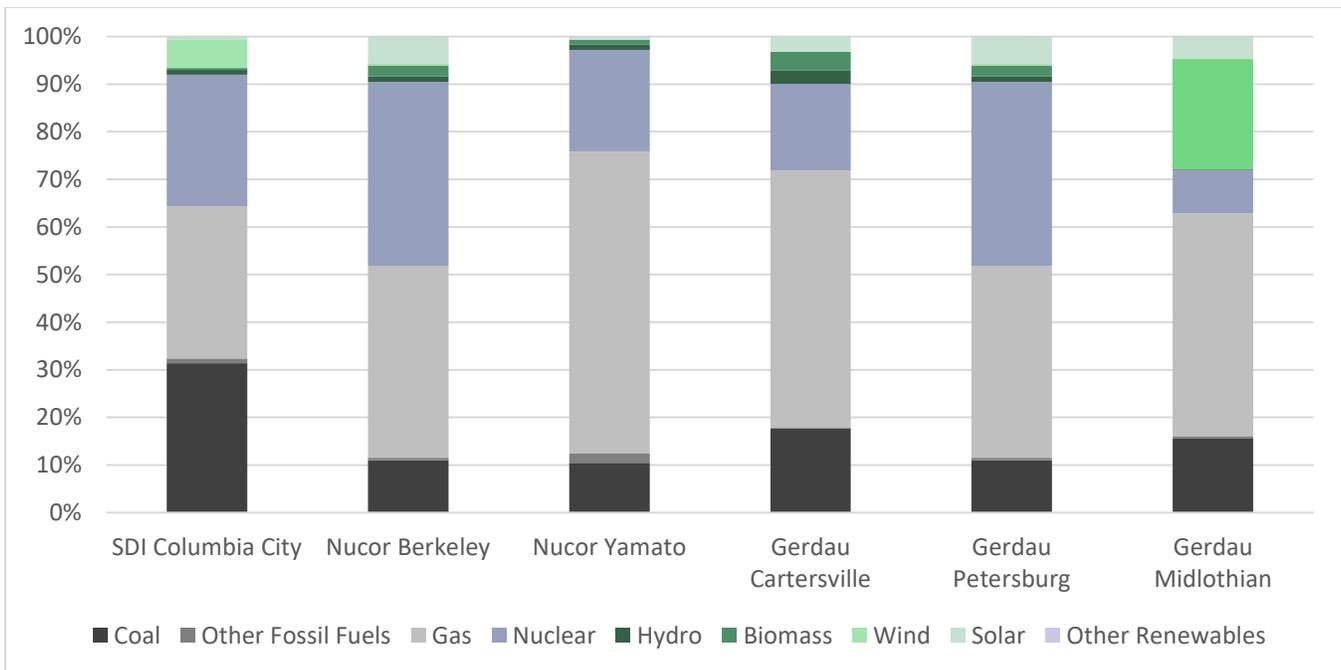


Figure 2: eGRID power mix split for each mill site

One site has a dedicated on-site solar facility operated by a third party with a documented power purchase agreement (PPA) and bundled Renewable Energy Certificates (RECs). This electricity was modeled using a region-specific solar dataset. The facility began operation in June 2023, and the mill purchased 100% of the electricity generated during the study period, with exclusive rights/responsibility to purchase the power generated. One other facility purchased RECs, a mix of solar and wind energy, for the study’s production year. The renewable energy associated with these RECs was confirmed by the supplier as retired from the system and is therefore included in the baseline results, in accordance with Smart EPD Part A requirements. The renewable electricity mix consisted of 60% wind and 40% solar. Additional details are presented in Table 45 in Annex C.

Inventory data for each site was then scaled down from an annual production level to a per metric ton of hot-rolled structural steel sections leaving the site. To account for home scrap generated in the section rolling unit process, the amount of the EAF unit process for each site was increased based on the amount of home scrap generated at that site. Therefore, more than 1 metric ton of the EAF process was modeled per 1 metric ton of the section rolling process. The production-weighted average was 1.06 metric tons of crude steel input (blooms/billets) per metric ton of hot-rolled structural sections produced.

The sorting and processing of recycled steel input (i.e., purchased external scrap) are accounted for in Module A1, as required in the Part B PCR. Theecoinvent dataset “sorting and pressing of iron scrap | iron scrap, sorted, pressed | Cutoff, U – RoW” was used to model the impacts associated with the incoming steel scrap at the steel mills. This dataset was modified to reflect the U.S. average electricity grid mix, and emissions from facility infrastructure were excluded.

To generate the average inventory and results from the six sites, a top-level process was modeled using production data in metric tons of the in-scope product produced from each site. The proportion of total production was calculated by dividing each individual site’s production by the total production from all six sites. These percentages were then used in the top-level openLCA process to create 1 metric ton of average product output. Table 6 provides a summary LCI for the average EAF unit process, and Table 7 provides a summary LCI for the average section rolling process to produce 1 metric ton of hot-rolled structural sections at the mills. As discussed previously, different natural gas datasets were used depending on whether each site provided emissions data that included fuel combustion. The complete inventory is included in Annex A.



Table 6: Summary LCI for the production-weighted average EAF steelmaking unit process

| Item | Quantity | Units |
|-----------------------------------|-------------|----------------|
| Inputs | | |
| External Scrap | 9.93E-01 | MT |
| Internal Scrap | 1.35E-02 | MT |
| Home Scrap | 6.76E-02 | MT |
| DRI | 3.96E-02 | MT |
| Pig Iron | 2.92E-02 | MT |
| Silicomanganese | 1.28E-02 | MT |
| Ferro Silicon | 1.23E-03 | MT |
| Other Alloying Elements | 2.29E-03 | MT |
| Lime (Total) | 3.17E-02 | MT |
| Refractories | 3.40E-03 | MT |
| Electrodes | 1.79E-03 | MT |
| Oxygen | 6.07E-02 | MT |
| Argon | 1.30E-03 | MT |
| Nitrogen | 1.13E-02 | MT |
| Municipal Water | 2.11E-01 | m ³ |
| Ground Water | 8.93E-01 | m ³ |
| Surface Water | 1.21E-02 | m ³ |
| Purchased Electricity | 5.54E+02 | kWh |
| Electricity Generated On-site | 1.01E+01 | kWh |
| Natural Gas Production | 5.93E+02 | MJ |
| Natural Gas Incl. Combustion | 9.01E+01 | MJ |
| Gasoline - for Internal Transport | 2.32E+00 | MJ |
| Diesel - for Internal Transport | 5.49E+01 | MJ |
| Propane - for Internal Transport | 7.99E-01 | MJ |
| Outputs | | |
| Product Output (Steel Blooms) | 1.00E+00 | MT |
| Internal Scrap | 1.35E-02 | MT |
| Slag | 1.46E-01 | MT |
| Hazardous Waste | 1.27E-03 | MT |
| Non-Hazardous Waste | 6.34E-03 | MT |
| Recycled Waste | 2.22E-02 | MT |
| Mill Scale | 1.28E-02 | MT |
| CO ₂ Emissions to Air | 7.91E-02 | MT |
| Other Emissions to Air | See Annex A | MT |
| Emissions to Water | See Annex A | MT |
| Water Emissions to Air | 1.01E+00 | m ³ |
| Water Discharge to Water | 7.06E-02 | m ³ |
| Wastewater to POTW | 3.91E-02 | m ³ |

Table 7: Summary LCI for the production-weighted average section rolling unit process

| Item | Quantity | Units |
|----------------------------------|-------------|----------------|
| Inputs | | |
| Steel Blooms | 1.06E+00 | MT |
| Purchased Electricity | 1.13E+02 | kWh |
| Electricity Generated On-site | 1.69E+00 | kWh |
| Natural Gas Production | 1.65E+03 | MJ |
| Natural Gas Incl. Combustion | 2.27E+02 | MJ |
| Municipal Water | 1.49E-01 | m ³ |
| Ground Water | 5.43E-01 | m ³ |
| Surface Water | 7.90E-03 | m ³ |
| Outputs | | |
| Product Output | 1.00E+00 | MT |
| Internal Scrap | 5.61E-02 | MT |
| CO ₂ Emissions to Air | 1.09E-01 | MT |
| Other Emissions to Air | See Annex A | MT |
| Emissions to Water | See Annex A | MT |
| Water Emissions to Air | 6.16E-01 | m ³ |
| Water Discharge to Water | 5.10E-02 | m ³ |
| Wastewater to POTW | 3.38E-02 | m ³ |

3.1.2 Use Stage

This stage includes product use over the specified RSL, which is set as equivalent to the building life defined as 75 years in the Smart EPD Part B PCR. Hot-rolled structural steel sections are typically installed when a building is constructed and not replaced until the building reaches its end-of-life. This stage covers impacts associated with use (B1) maintenance (B2), repair (B3), replacement (B4), and refurbishment (B5), and operational water and energy use (B6-B7) of the installed product. Since the RSL of hot-rolled structural steel sections is expected to be at least equivalent to the building service life, there are no associated emissions or impacts from the use of the product, in accordance with PCR Part B, Section 7.1.7.4.

Table 8: Reference Service Life

| Name | Value | Unit |
|---|--|-------|
| Description of scenario | Use of installed hot-rolled structural steel sections in a building with a service life of 75 years. | |
| RSL | 75 | years |
| Declared product properties (at the gate) and finishes, etc. | Varies based on application (see Section 2.1) | N/A |
| Design application parameters (if instructed by the manufacturer), including references to the appropriate practices and application codes) | Varies based on application (see Section 2.1) | N/A |

3.1.3 End-of-life Stage

The end-of-life stage includes demolition (C1), transport of the steel products to a recycling center or landfill (C2), waste processing (C3), and emissions associated with landfilling the portion of the steel product that is not recycled (C4). In accordance with the PCR Part B, Section 7.1.7.5, the waste processing module (C3) covers the processing of materials for disposal that are not intended for recycling or reuse, while the processing impacts for recycled materials are accounted for in A1. For this product, no waste processing is required at stage C3; therefore, no emissions are generated. As a result, the C3 stage impacts are reported as zero for the product system. Details are provided in Table 9 below.

Due to the lack of region-specific data, the impacts for the demolition stage (C1) were modeled using secondary data from an European study, *Recording Sustainability Indicators for the Value Chain – Construction and Demolition in Steel Construction* (Siebers, 2020), which provides life cycle inventory data for steel construction and demolition. Diesel and electricity consumption figures from Table A42 in the publication were used to model dismantling and demolition activities occurring in the C1 Module.

For transportation to end-of-life (C2), distances and transportation modes to send steel from building demolition to the disposal site or recycling center, were adopted from EPA’s WARM model (EPA, 2023). A distance of 32 km (20 miles) was used to model transportation between the building site and landfill or recycling center.

Table 9: End of Life (C1-C4)

| Name | | Value | Per declared unit Unit |
|--|--|--|-----------------------------|
| Description of scenario | | End-of-life stage for hot-rolled structural steel sections, including demolition, transportation, and end-of-life disposition processes | |
| Module C1: Demolition | | 1.08 5.97 | kWh electricity L diesel |
| Module C1: Name of LCI dataset used for modeling | | Ecoinvent v3.10: market group for electricity, medium voltage electricity, medium voltage Cutoff, U - US market for diesel, burned in building machine diesel, burned in building machine Cutoff, U - GLO | |
| Module C2: Transport distance | | 32 | km |
| Module C2: Transport mode/fuel | | Diesel truck | |
| Module C2: Name of LCI dataset(s) used for modeling | | Transport, combination truck, short-haul, diesel powered - US (US LCI, mapped to ecoinvent v3.10: diesel production, petroleum refinery operation diesel Cutoff, U - RoW) | |
| Recovery (specified by type) | Reuse | 0 | kg |
| | Recycling | 970 | kg |
| | Module C4: Landfill | 30 | kg |
| | Module C4: Name of LCI dataset used for modeling | Ecoinvent v3.10: treatment of scrap steel, inert material landfill scrap steel Cutoff, U - RoW | |
| Module C3: Waste Processing (sorting/shredding) (based on recycling mass) | | N/A | |
| Removals of biogenic carbon (excluding packaging) | | N/A | |
| Further assumptions for scenario development (e.g., frequency and time period of use, number of occupants) | | N/A | |

3.1.4 Transport from Mills to Fabrication Data Collection and Modeling

In the original fabrication study conducted to inform AISC’s 2021 EPD background report (Sphera, 2021), the production-weighted average transportation distance for 1 metric ton of hot-rolled structural steel sections shipped from the mills to fabrication sites was 945 km. The mode split of 25% by truck and 75% by rail was provided by AISC in consultation with steel producers participating in this study. The additional mass of steel product required to account for the fabrication scrap was also modeled based on 1.0771 MT of steel product required per 1 MT fabricated steel product. Therefore, total transport of 1,017 MT.km (945 km * 1.0771 MT = 1.017 MT.km) was modeled for the A2 stage as shown in Table 10.

Table 10: A2 unit process for transporting 1.0771 metric tons of hot-rolled structural steel from the mills to the fabricators

| Item | Quantity | Units |
|-----------------|---------------------|-------|
| Truck Transport | $1017 * 0.25 = 254$ | MT.km |
| Rail Transport | $1017 * 0.75 = 763$ | MT.km |

3.1.5 Fabrication Data Collection and Modeling

Primary data on product fabrication was collected from a subset of AISC’s member fabricators for 12 continuous months of production in 2019 and 2020 as part of AISC’s 2021 industry-average fabricated structural sections and plate EPDs (Sphera, 2021). The 2019-2020 inventory values were statistically similar to those collected in the first data collection back in 2015 of more than 250 fabricators.

The data collection process entailed sending a survey to AISC’s approximately 1,000 fabricator members. In total, 80 fabrication facilities provided primary data for their facilities, which were aggregated into a production-weighted average inventory for the average, 10th, and 90th percentile. The average inventory was used in AISC’s 2021 EPD to model A3 impacts.

For the current study, as described in Section 2.1, the previously collected fabrication LCI dataset was updated with background datasets from the ecoinvent v3.10 database. The datasets that were the closest match to those selected by Sphera from the GaBi database were chosen. Several datasets were used to model the different electrode types and the electricity consumed at the fabricators. The AISC 2021 EPD background report did not report the composition shares of materials required to make the electrodes; therefore, research was conducted to determine the closest match for each type of electrode and the constituent parts. Safety data sheets (SDS) were used to estimate the percent composition. If the SDS provided a range for the amount of a constituent, the average value was used. Global average background data on steel cold rolled coil (CRC) and wire rod was supplied by The World Steel Association from their 2022 average LCI data release. The complete list of background datasets modeled for the fabrication process is included in Annex B. Table 11 shows the types of electrodes mapped, the constituent parts, and percentage each part represents of the total mass.

A similar process was conducted for mapping the welding flux. Table 12 shows the welding flux constituent parts, and the percentage each part represents of the total mass.

Table 11: Electrode composition by type

| Electrode Type | Constituents | % of Total Mass |
|--|------------------------------|-----------------|
| Stick Welding Electrodes (Washington Alloy, 2023) | | |
| | Steel Cold Rolled Coil (CRC) | 78.25 (balance) |
| | Calcium Carbonate | 1.25 |
| | Titanium Oxide | 5.00 |
| | Manganese | 1.50 |
| | Zircon | 1.00 |
| | Cellulose | 2.50 |
| | Potassium Silicate | 2.00 |
| | Sodium Silicate | 2.00 |
| | Kaolin | 2.50 |
| | Titanium Oxide Dust | 2.50 |
| | Zirconium | 0.50 |
| | Total | 100% |
| Flux Core Electrodes (Washington Alloy, 2023) | | |
| | CRC | 82.75 (balance) |
| | Calcium Carbonate | 1.25 |
| | Titanium Oxide | 5.00 |
| | Manganese | 2.50 |
| | Silicon | 2.50 |
| | Sodium Silicate | 2.00 |
| | Aluminum | 1.50 |
| | Titanium Oxide Dust | 2.50 |
| | Total | 100% |
| Submerged Arc Electrodes (Pinnacle Alloys, 2022) | | |
| | CRC | 89.90 (balance) |
| | Silica | 1.50 |
| | Aluminum Oxide | 1.50 |
| | Barium | 4.50 |
| | Manganese | 2.00 |
| | Magnesium | 0.60 |
| | Total | 100% |
| Metal Core Electrodes (Washington Alloy, 2023) | | |
| | CRC | 96.25 (balance) |
| | Calcium Carbonate | 1.25 |
| | Manganese | 2.50 |
| | Total | 100% |
| Gas Metal Arc Electrodes (Pinnacle Alloys, 2022) | | |
| | CRC | 98.00 (balance) |
| | Manganese | 2.00 |
| | Total | 100% |

Table 12: Welding flux composition

| Electrode Type | Constituents | % of Total Mass |
|--------------------------------------|------------------|-----------------|
| Welding Flux (Aufhauser, n.d) | | |
| | Steel Wire Rod | 75.00 (balance) |
| | Aluminum | 2.50 |
| | Barium Fluoride | 7.50 |
| | Fluorspar | 5.00 |
| | Magnesium Oxide | 1.50 |
| | Manganese | 2.50 |
| | Silica | 1.00 |
| | Titanium Dioxide | 5.00 |
| | Total | 100% |



The fabrication study, as part of AISC’s 2021 EPD, modeled electricity based on the U.S. subregional grid mix for each of the 80 fabricator facility locations for which data was provided. The EPD background report provided a list of grid mix regions that were modeled, but did not include the percentage share for each region represented by the industry-average LCI. In order to fill this gap and to better represent a U.S.-average process, AISC provided fabrication throughput in mass for all fabricator members for the 2023 calendar year, split by U.S. state. These states were then mapped to North American Electric Reliability Corporation (NERC) subregions, which are the most granular electricity subregions for the U.S. available in ecoinvent, based on location. If a state spanned more than one subregion, AISC provided guidance on where the majority of fabricators in that state were located, which allowed one NERC subregion to be chosen for each state. To make the top-level process in openLCA, each subregion was assigned a percent of total annual fabrication, and those proportions were used to model 1 metric ton of the fabrication process. **Error! Not a valid bookmark self-reference.** shows each state in the U.S. and the mapped subregions modeled.

Table 13: U.S. states and mapped NERC subregions based on fabricator geography

| State in U.S. | Mapped NERC Region | State in U.S. | Mapped NERC Region |
|---------------|--------------------|---------------|--------------------|
| AL | SERC | NC | SERC |
| AR | SERC | ND | MRO |
| AZ | WECC | NE | MRO |
| CA | WECC | NH | NPCC |
| CO | WECC | NJ | RF |
| CT | NPCC | NM | WECC |
| DE | RF | NV | WECC |
| FL | SERC | NY | NPCC |
| GA | SERC | OH | RF |
| HI | HICC | OK | MRO |
| IA | MRO | OR | WECC |
| ID | WECC | PA | RF |
| IL | RF | PR | PR |
| IN | RF | RI | NPCC |
| KS | MRO | SC | SERC |
| KY | SERC | SD | MRO |
| LA | SERC | TN | SERC |
| MA | NPCC | TX | TRE |
| MD | RF | UT | WECC |
| ME | NPCC | VA | SERC |
| MI | RF | VT | NPCC |
| MN | MRO | WA | WECC |
| MO | SERC | WI | MRO |
| MS | SERC | WV | RF |
| MT | WECC | WY | WECC |

Table 14 shows the percentage split of each NERC subregion based on total fabrication throughput. These shares were used to create an industry-average electricity grid mix for the fabrication process.

Table 14: Percent of electricity share based on fabrication throughput by NERC subregion

| NERC Subregion | % of Total Fabrication |
|----------------|------------------------|
| SERC | 34% |
| WECC | 15% |
| NPCC | 6.4% |
| RF | 16% |
| HICC | 0.0032% |
| MRO | 20% |
| PR | 0.097% |
| TRE | 8.4% |
| Total | 100% |

Table 15 shows the unit process for the average, 10th, and 90th percentile of 1 metric ton of fabricated hot-rolled structural steel sections. Where 10th and 90th percentile values were shown as a ‘N/A’ in the AISC 2021 EPD background report, the average value was used as a proxy. This was the case for ‘fluids & oil’ and ‘welding flux’ on the input side, and all outputs excluding ‘steel scrap’ and ‘shop waste’.

Table 15: Unit process for average, 10th percentile, and 90th percentile for 1 metric ton of fabricated hot-rolled structural steel sections

| Item | Average Amount | 10 th Percentile Amount | 90 th Percentile Amount | Units |
|---------------------------------|----------------|------------------------------------|------------------------------------|-------|
| Inputs | | | | |
| Structural Steel (from Mills) | 1.08E+03 | 1.00E+03 | 1.14E+03 | kg |
| Fluids & Oil | 3.32E-01 | 3.32E-01 | 3.32E-01 | kg |
| Stick Welding Electrodes | 4.88E-02 | 2.72E-03 | 5.32E-01 | kg |
| Flux Core Electrodes | 1.36E+00 | 4.74E-02 | 3.24E+00 | kg |
| Submerged Arc Electrodes | 2.00E-01 | 1.22E-02 | 1.69E+00 | kg |
| Metal Core Electrodes | 4.78E-01 | 1.91E-01 | 3.43E+00 | kg |
| Gas Metal Arc Electrodes | 5.75E-01 | 1.68E-02 | 2.89E+00 | kg |
| Steel Wire | 2.09E-03 | 8.33E-04 | 5.77E-01 | kg |
| Welding Flux | 1.59E-02 | 1.59E-02 | 1.59E-02 | kg |
| Acetylene, Compressed | 1.02E-01 | 9.19E-04 | 2.55E-01 | kg |
| Argon, Compressed | 3.35E-01 | 1.87E-03 | 1.10E+00 | kg |
| Argon, Liquid | 1.27E+00 | 1.06E-02 | 7.73E+00 | kg |
| Carbon Dioxide, Compressed | 3.80E-01 | 1.34E-02 | 2.47E+00 | kg |
| Carbon Dioxide, Liquid | 1.60E+00 | 9.78E-02 | 5.77E+00 | kg |
| Helium, Compressed | 1.78E-04 | 1.89E-01 | 1.67E+00 | kg |
| Natural Gas, Compressed | 5.57E-02 | 1.54E-02 | 1.20E+00 | kg |
| Nitrogen, Compressed | 1.00E-01 | 1.83E-03 | 5.06E-01 | kg |
| Nitrogen, Liquid | 8.04E-02 | 6.04E-03 | 1.06E+00 | kg |
| Oxygen, Compressed | 3.33E-01 | 7.55E-03 | 1.54E+00 | kg |
| Oxygen, Liquid | 3.04E+00 | 4.50E-03 | 7.05E+00 | kg |
| Propane, Compressed | 3.43E-01 | 2.68E-03 | 5.97E-01 | kg |
| Propane, Liquid | 7.79E-02 | 3.10E-03 | 1.63E-01 | kg |
| Propylene, Compressed | 8.95E-02 | 2.41E-02 | 4.83E-01 | kg |
| Propylene, Liquid | 9.19E-02 | 3.07E-02 | 6.89E-01 | kg |
| Electricity | 4.64E+02 | 1.70E+02 | 8.41E+02 | MJ |
| Propane, Internal Transport | 5.65E-01 | 3.52E-02 | 2.28E+00 | kg |
| Gasoline, Internal Transport | 1.68E-01 | 3.31E-02 | 8.99E-01 | kg |
| Diesel, Internal Transport | 2.12E+00 | 2.91E-01 | 5.23E+00 | kg |
| Kerosene, Internal Transport | 3.05E-01 | 4.12E-02 | 3.02E+01 | kg |
| Thermal Energy from Natural Gas | 1.58E+01 | 2.50E+00 | 6.49E+02 | MJ |
| Inbound Truck Transport | 2.16E+00 | 2.94E-03 | 1.86E-03 | MT.km |
| Outputs | | | | |
| Fabricated Structural Steel | 1.00E+03 | 1.00E+03 | 1.00E+03 | kg |

| Item | Average Amount | 10 th Percentile Amount | 90 th Percentile Amount | Units |
|---------------------------------|----------------|------------------------------------|------------------------------------|-------|
| Steel scrap | 7.71E+01 | 7.77E+00 | 1.58E+02 | kg |
| Shop Waste | 9.66E+00 | 1.83E+00 | 2.76E+01 | kg |
| Used Oil | 3.32E-01 | 3.32E-01 | 3.32E-01 | kg |
| Argon Emissions to Air | 7.92E-02 | 7.92E-02 | 7.92E-02 | kg |
| Carbon Dioxide Emissions to Air | 2.43E+00 | 2.43E+00 | 2.43E+00 | kg |
| Helium Emissions to Air | 1.78E-04 | 1.78E-04 | 1.78E-04 | kg |
| Nitrogen Emissions to Air | 1.81E-01 | 1.81E-01 | 1.81E-01 | kg |
| Oxygen Emissions to Air | 6.84E-01 | 6.84E-01 | 6.84E-01 | kg |
| Water Emissions to Air | 1.12E+00 | 1.12E+00 | 1.12E+00 | kg |

3.2 Background Data

Background data was sourced from the USLCI and ecoinvent v3.10. All background datasets modeled in this study are listed in Annex A.

3.3 Data Quality

3.3.1 Requirements

The key requirement for data quality is that data be as accurate and representative as possible. Data quality evaluations are described in Table 16 and are based on the ISO 14044:2006 standard. To fulfill these requirements and to ensure reliable results, primary data in combination with representative, industry association data and consistent background LCI information from ecoinvent (v3.10) were used.



Table 16: Data quality requirements and evaluation of data quality

| Parameter | Evaluation of Data Quality for this Study |
|-----------------------|--|
| Time-related coverage | <p>Manufacturing data from the six mill sites (A1) is representative of the 2023 calendar year. Primary data was collected from the six sites for 12 consecutive months representing the production year 2023. Background data from ecoinvent v3.10 represents the year 2023 (based on the release date of the database). Temporal representativeness for the mills is considered to be high.</p> <p>Primary data for the A2 transportation stage is representative of the years 2019 and 2020. While those distances were utilized in this assessment, the proportional split of transport by mode was updated per information from AISC and its members to reflect current industry practices. Additionally, datasets were updated using the USLCI and mapped to ecoinvent v3.10, which is representative of the 2023 year of data. Therefore, the temporal representativeness of the A2 stage data is considered to be moderate.</p> <p>Fabrication data (A3) was collected from the fabricator sites representing the 2019 and 2020 production years. For this study, the primary data was mapped to updated background datasets to approximate the 2023 year of data. Temporal representativeness of the fabricator sites is considered to be moderate.</p> |
| Geographical coverage | <p>All primary data is representative of the U.S. with 100% coverage of hot-rolled structural steel sections production included in the study. U.S. and U.S. subregion-specific datasets were utilized where possible, such as for electricity modeling. Rest of World (RoW) and Global (GLO) datasets were used where appropriate for raw material sourcing locations and when specific regional datasets were unavailable. Geographical representativeness is considered to be high.</p> |
| Technology coverage | <p>Data from each of the six mill sites and 80 fabricator sites were collected and are representative of the manufacturing and fabrication processes from those sites. As the analysis represents AISC’s industry-average hot-rolled structural steel sections, and the six mills represent a majority share of manufacturing, and the 80 fabricator sites represent good coverage of the fabrication process, the technology coverage of the assessment is considered to be high.</p> |
| Precision | <p>Primary data is based on actual manufacturing data for the in-scope products produced at the mills and fabricators. Where specific data points were unavailable, reasonable estimates were developed and documented.</p> |
| Completeness | <p>All relevant process steps within the study boundary were considered and included within this study. Efforts were made to cross-check data provided from each mill, identify gaps, and seek data from the mills or gap-fill with average data from the other sites. Where specific data points were unavailable, representative estimates were used.</p> |
| Representativeness | <p>Data collected and modeled in this study is considered to be representative of the defined time-related, geographical, and technological scope.</p> |
| Consistency | <p>The study methodology conforms to the relevant ISO standards and PCRs and is applied to all components of the analysis. Additionally, to ensure consistency, only primary and secondary data of the same level of detail and granularity were used.</p> |
| Reproducibility | <p>The study results would be reproducible through the provision of this report, along with supplemental and confidential documentation that was developed throughout this assessment.</p> |
| Sources of the data | <p>Data is derived from credible sources and databases, with reference to the primary or secondary nature of the data. Data sources are in conformance with the PCR requirements.</p> |
| Uncertainty | <p>The primary fabrication data is representative of the 2019 and 2020 years of fabrication. It was assumed that the data is still representative of fabrication currently; however, current values may differ in reality.</p> <p>Other sources of uncertainty are associated with data gaps and assumptions. One mill site did not provide the amount of electrodes used; however, as all other mill sites provided electrodes data, the missing value was supplemented with conservative proxy data from the other sites. Another mill requested the use of upstream transportation assumptions from another mill owned by the same company as a proxy. These values may differ in reality.</p> |

3.3.2 Gaps, Assumptions, and Limitations

This section identifies data gaps, assumptions, and limitations, and discusses how they are anticipated to affect results.

Table 17: Data gaps, assumptions, and limitations

| Description | Potential Implication |
|--|---|
| Use of proxy data for inbound transport distances and modes | Although the mill sites provided the majority of their inbound transport data, transportation data for some inputs were not provided. When this occurred, gap-filling took place by applying the values in Table 4, differentiating between alloying elements (based on average transport data for all sites) and other material inputs (aligned with the 2020 AISI steel LCI project report). For one mill site, the company provided transportation distances for steel scrap, which is the largest material input at the site, and requested that average transportation mode and distance data be used otherwise from another site owned by the company. These modes and distances may not be the case in reality. As upstream transportation is a relatively minor contributor to the impacts assessed in this study, this assumption is expected to have a minor effect on overall cradle-to-mill-gate results. |
| Use of proxy data for missing steel mill material inputs | Where mill sites did not provide data on key materials, proxy values were used based on average values from other sites. One mill site did not provide the amount of electrodes used; therefore, the missing value was supplemented with average data from other sites as a proxy. Another site provided two sets of water input data that were orders of magnitude too high and then too low, so average data from other sites was assigned as a proxy. These values may be different in reality. This applied to only minor inputs and average values were used from other sites; therefore, this assumption is expected to have a minor effect on overall cradle-to-mill-gate results. |
| Use of assumption for allocation ratio between EAF and section rolling processes at mill sites | Where mill sites provided certain data points for the entire facility, an allocation assumption of 50:50 split across the EAF steelmaking and section rolling unit processes was applied prior to scaling to in-scope production. This occurred most commonly for on-site transportation fuels, wastes, and non-CO ₂ air emissions. While this may slightly affect the amount of impact assigned to the EAF vs the section rolling processes, this assumption is expected to have a minor impact on overall site-level results. |
| Use of USLCI transportation factors | Per the Smart EPD PCR requirements, the USLCI database was used for transportation datasets. Transport datasets were identified in the USLCI for each mode (truck, rail, ship, barge), and then mapped to best-fit upstream datasets using ecoinvent v3.10 for all non-elementary flows. USLCI transportation data is derived from source data updated in 2024. The diesel truck transport dataset is based on the vehicle fleet as estimated in 2024. The database is publicly available and is required for transportation impacts in the Smart EPD Part B PCR. |
| Use of proxy data to gap-fill fabrication values | Fabrication data supplied by the 2021 AISC EPD background report contained some 'N/A' values for the 10 th and 90 th percentile fabrication ranges for certain inputs, wastes, and emissions. These missing values were supplemented with average values as a proxy; however, they would likely be different in reality. Fabrication is not a major contributor to overall cradle-to-mill-gate results and the average value was used in the baseline results for this study; therefore, this assumption is expected to have a minor effect on overall cradle-to-mill-gate results. |
| Use of assumptions for fabrication material input compositions | Electrode and welding flux datasets were mapped using SDS documents as these items contained multiple components and the 2021 AISC EPD background report did not report the material composition shares. When a percentage of an ingredient was given as a range, half of the maximum value was used, and any remaining percent of the total was balanced with steel inputs. This may not be the case in reality. As electrodes and welding flux were only minor contributors to impact and the SDS's enabled reasonable approximations of the composition, this assumption is expected to have a minor impact on overall cradle-to-mill-gate product results. |

3.4 EPD Data Specificity

Smart EPD Part A Section 9.3.4.2 allows EPDs to optionally report the percentage of supply chain-specific data in accordance with the ACLCA 2022 PCR Open Standard Addendum: *Guidance for Determining EPD Types and Calculating and Communicating Data Specificity Through the Supply Chain*. However, as stated in the ACLCA guidance document (note on Section 7.1.1), manufacturer-average and industry-average EPDs shall not perform the supply chain specificity calculation. Only facility-specific EPDs may report a supply chain specificity greater than 0%. Therefore, data specificity is not calculated in this LCA.

While not quantified, the study includes primary data for most of the key contributing flows, including primary data on energy use, utilities, raw material and ancillary material consumption, water, wastes, and emissions at the steel mills; distance and mode of transport for steel scrap comprising the majority of the product; and direct-reduced iron used in place of scrap at one facility. Other key flows represented by secondary data include pig iron consumption and electricity grid mixes, which were based on the eGRID fuel mix for each facility location.

4 LCIA Results

The life cycle impact assessment (LCIA) phase connects the LCI results to potential environmental impacts. This section presents the potential environmental impact and inventory metric results described in the goal and scope for this study and accompanying discussion to interpret the results. All results are presented per 1 metric ton of production-weighted average hot-rolled structural steel sections, unfabricated and with fabrication, as described in Section 2.1.2.

These LCIA results are relative expressions and do not predict impacts on category endpoints, the exceedance of thresholds, safety margins, or risks.

4.1 Industry-Average Hot-Rolled Structural Steel Sections Results (Excluding Fabrication)

The baseline results for this study are for 1 MT of production-weighted hot-rolled structural steel sections produced in the U.S., excluding fabrication. Per the Smart EPD Part B PCR guidance for unfabricated mill products, results categories are organized as follows:

- A1 – “Extraction and processing of feedstock materials”, i.e., this category includes the upstream production of iron and steel inputs, as well as alloy materials.
- A2 – “Transportation of the feedstock to the mill facility”, i.e., this category includes the inbound transportation of feedstock materials to the EAF process.
- A3 – “Mill operations”, i.e., this category includes production of ancillary materials (e.g., refractory, lubricants, electrodes, etc.), energy requirements (e.g., electricity, natural gas, mobile fuels), water use, packaging (after section rolling), transport of non-A1 materials to the mill, waste and waste transport, and emissions.
- B1-B7 – “Product use”, i.e., this category includes impacts associated with the use stage of the product in a building setting. There are no associated emissions or impacts from the use of the product, in accordance with PCR Part B Section 7.1.7.4, since the RSL of the product exceeds the estimated 75-year service life of the project.
- C1 – “Deconstruction/Demolition”, i.e., this module includes all deconstruction and demolition activities taking place at the existing project site including sorting.
- C2 – “Transport”, i.e., this module includes the transportation of the steel product to be recovered or landfilled from the existing project site to a recycling center or landfill.
- C3 – “Waste Processing”, i.e., this module includes the processing of material for disposal not intended for recycling or reuse.
- C4 – “Disposal”, i.e., this module includes disposal impacts associated with landfill or incineration processes.

Figure 3 shows the results of the industry-average hot-rolled structural steel sections, excluding fabrication, produced by the mills for each LCIA impact category under study, with sub-categories shown as percentages of the total result. Table 18 shows the LCIA results for 1 metric ton of industry-average hot-rolled structural steel sections, split by life cycle modules. Table 19 through Table 21 show resource use, output flows and wastes, and carbon emissions and removals results for 1 metric ton of industry-average hot-rolled structural steel sections.

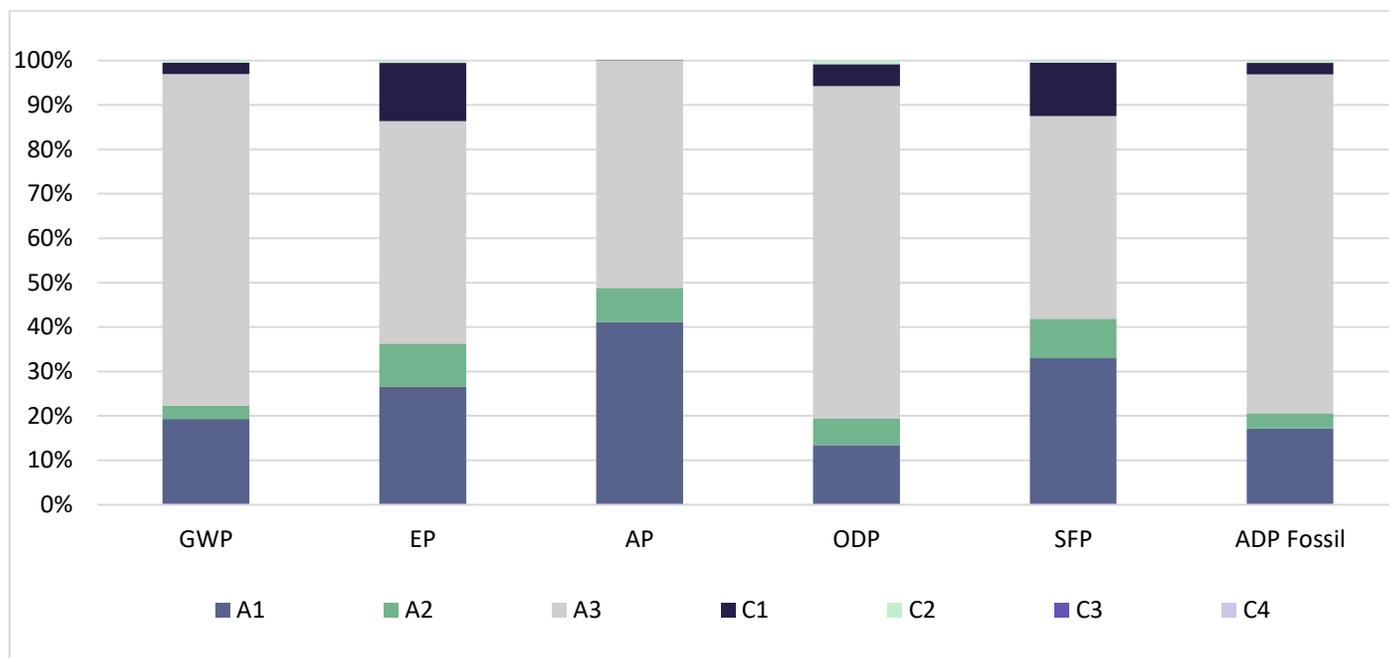


Figure 3: LCIA results of industry-average hot-rolled structural steel sections, in percent contribution

Table 18: LCIA results for 1 metric ton of industry-average hot-rolled structural steel sections

| Impact Category | Units | Total (A1-A3) | A1 | A2 | A3 | B1-B7 | C1 | C2 | C3 | C4 |
|------------------------|--------------------------|---------------|----------|----------|----------|----------|----------|----------|----------|----------|
| GWP-total | kg CO ₂ -eq | 8.98E+02 | 1.79E+02 | 2.78E+01 | 6.91E+02 | 0.00E+00 | 2.34E+01 | 4.25E+00 | 0.00E+00 | 1.88E-01 |
| GWP-fossil | kg CO ₂ -eq | 8.97E+02 | 1.79E+02 | 2.78E+01 | 6.91E+02 | 0.00E+00 | 2.34E+01 | 4.25E+00 | 0.00E+00 | 1.88E-01 |
| GWP-biogenic | kg CO ₂ -eq | 4.49E-01 | 9.87E-02 | 2.10E-03 | 3.48E-01 | 0.00E+00 | 2.03E-03 | 2.00E-04 | 0.00E+00 | 4.60E-05 |
| GWP-luluc | kg CO ₂ -eq | 2.39E-01 | 7.27E-02 | 4.77E-03 | 1.62E-01 | 0.00E+00 | 2.24E-03 | 1.80E-04 | 0.00E+00 | 9.66E-05 |
| ODP | kg CFC ₁₁ -eq | 7.10E-06 | 1.01E-06 | 4.52E-07 | 5.64E-06 | 0.00E+00 | 3.72E-07 | 5.76E-08 | 0.00E+00 | 5.72E-09 |
| AP | kg SO ₂ -eq | 2.80E+00 | 1.15E+00 | 2.15E-01 | 1.43E+00 | 0.00E+00 | 1.92E-01 | 8.10E-03 | 0.00E+00 | 1.20E-03 |
| EP | kg N-eq | 1.64E+00 | 5.04E-01 | 1.84E-01 | 9.51E-01 | 0.00E+00 | 2.49E-01 | 8.37E-03 | 0.00E+00 | 1.31E-03 |
| SFP | kg O ₃ -eq | 4.44E+01 | 1.67E+01 | 4.50E+00 | 2.31E+01 | 0.00E+00 | 6.10E+00 | 2.02E-01 | 0.00E+00 | 3.20E-02 |
| ADP_f | MJ | 1.14E+04 | 2.02E+03 | 4.10E+02 | 8.98E+03 | 0.00E+00 | 3.03E+02 | 5.38E+01 | 0.00E+00 | 4.55E+00 |

Table 19: Resource use results for 1 metric ton of industry-average hot-rolled structural steel sections

| Indicator | Units | Total (A1-A3) | A1 | A2 | A3 | B1-B7 | C1 | C2 | C3 | C4 |
|-------------------|----------------|---------------|----------|----------|----------|----------|----------|----------|----------|----------|
| RPR _E | MJ | 1.73E+03 | 0.00E+00 | 0.00E+00 | 1.73E+03 | 0.00E+00 | 2.88E+00 | 1.18E-01 | 0.00E+00 | 4.27E-02 |
| RPR _M | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NRPR _E | MJ | 1.28E+04 | 2.27E+03 | 4.61E+02 | 1.01E+04 | 0.00E+00 | 3.06E+02 | 5.36E+01 | 0.00E+00 | 4.57E+00 |
| NRPR _M | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| SM | kg | 9.90E+02 | 9.90E+02 | 0.00E+00 |
| RSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NRSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RE | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FW | m ³ | 3.43E+00 | 3.09E-01 | 3.43E-02 | 3.09E+00 | 0.00E+00 | 1.12E-02 | 5.90E-04 | 0.00E+00 | 2.20E-04 |

Table 20: Waste and output results for 1 metric ton of industry-average hot-rolled structural steel sections

| Indicator | Units | Total (A1-A3) | A1 | A2 | A3 | B1-B7 | C1 | C2 | C3 | C4 |
|-----------|-------|---------------|----------|----------|----------|----------|----------|----------|----------|----------|
| HWD | kg | 3.29E-01 | 2.96E-02 | 3.29E-03 | 2.96E-01 | 0.00E+00 | 2.09E-03 | 3.80E-04 | 0.00E+00 | 2.91E-05 |
| NHWD | kg | 6.21E+01 | 5.59E+00 | 6.21E-01 | 5.59E+01 | 0.00E+00 | 1.96E-01 | 7.50E-03 | 0.00E+00 | 3.00E+01 |
| HLRW* | kg | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| ILLRW* | kg | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| CRU | kg | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| MR | kg | 5.61E+01 | 0.00E+00 | 0.00E+00 | 5.61E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 9.70E+02 |
| MER | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| EE | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

*Data on radioactive waste disposal is not available in ecoinvent as an elementary flow. As such, impacts for HLRW and ILLRW are not reported by ACLCA guidance (ACLCA, 2018).

Because the product does not contain, or contains only negligible amounts of, bio-based materials from renewable resources, biogenic carbon emissions and removals are not reported in this study.

Table 21: Carbon emissions and removals results for 1 metric ton of industry-average hot-rolled structural steel sections

| Indicator | Units | A1 | A2 | A3 | Total |
|-----------|------------------------|-----|-----|-----|-------|
| BCRP | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| BCEP | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| BCRK | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| BCEK | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| BCEW | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| CCE | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| CCR | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| CWNR | kg CO ₂ -eq | N/A | N/A | N/A | N/A |

* Refer to Section 2.6 for discussion of carbon emissions and removals.

Results Disclaimer: It is recognized that by following the typical ISO 21930:2017 definitions of module A1, A2 and A3 for a specific production facility, inconsistencies will occur in classifying individual processes as either A1 or A3 based on the scope of the operations that take place at a given facility. Care must be taken not to compare A1, A2 or A3 on an individual basis for a given product from various mill producers, but, instead on the aggregated total of A1, A2 and A3. Separate A1, A2 and A3 values are provided for a better understanding of the processes taking place at a given facility and a greater level of transparency.

Construction product environmental impact results provide a sufficient basis for comparison only when considered in the context of the construction works project. In all cases of comparing construction products, the principle that the basis for comparison of the assessment is the construction works level shall be maintained by ensuring that the same functional requirements are met and the criteria in ISO 21930:2017 Section 5.5 “Comparability of EPDs for construction products” are satisfied.

4.1.1 Hot-Rolled Structural Steel Sections Results Including Module D

This section presents results for Module D, capturing benefits and burdens beyond the system boundary. The assumptions are summarized in Table 22, and the results are presented in as presented in Table 23.

End-of-life allocation was applied to calculate Module D results in accordance with the avoided burden approach defined by the World Steel Association (World Steel Association, 2025). Using this approach, Module D is calculated based on the benefits of recycling net scrap output from the product system. For industry-average hot-rolled structural steel sections, this calculation uses the World Steel Association’s Value of Scrap LCI dataset (based on ecoinvent v3.10 and the 2022 data release) (World Steel Association, 2025). The net scrap was determined by subtracting the industry average scrap input to steel production from the

amount of steel recycled at end-of-life, resulting in a net scrap yield of 5%, which is accounted for in Module D (eqn. 1).

$$e_{module\ D1} = (M_{MR\ out} - M_{MR\ in}) = (97\% - 92\%) = 5\% \quad eqn. 1$$

$M_{MR\ out}$: Percentage of scrap steel exiting the product system that is sent for recycling
 $M_{MR\ in}$: Percentage of scrap steel input to the product system

Table 22: Reuse, Recover, and/or Recycling Potentials (D), Relevant Scenario Information

| Name | Value | Unit |
|--|--|------|
| Description of scenario | Net benefit of recycling steel scrap recovered at end-of-life | |
| Recycled content of product | 92 | % |
| Net energy benefit from energy recovery from waste treatment declared as exported energy in C3 (R>0.6) | Not Applicable | MJ |
| End of Life Recovery Rate | 97 | % |
| Data Source for LCI of scrap (if used) | World Steel Association, 2025 | |
| Net energy benefit from thermal energy due to treatment of waste declared as exported energy in C4 (R<0.6) | Not applicable | MJ |
| Net energy benefit from material flow declared in C3 for energy recovery | Not applicable | MJ |
| Process and conversion efficiencies | World Steel Association LCI of scrap accounts for average steel scrap recycling process efficiency | |

Table 23: LCIA results for 1 metric ton of industry-average hot-rolled structural steel sections including Module D

| Impact Category | Units | Total (A1-A3) | A1 | A2 | A3 | B1-B7 | C1 | C2 | C3 | C4 | D |
|------------------|--------------------------|---------------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|
| GWP-total | kg CO ₂ -eq | 8.98E+02 | 1.79E+02 | 2.78E+01 | 6.91E+02 | 0.00E+00 | 2.34E+01 | 4.25E+00 | 0.00E+00 | 1.88E-01 | -8.68E+01 |
| GWP-fossil | kg CO ₂ -eq | 8.97E+02 | 1.79E+02 | 2.78E+01 | 6.91E+02 | 0.00E+00 | 2.34E+01 | 4.25E+00 | 0.00E+00 | 1.88E-01 | -8.68E+01 |
| GWP-biogenic | kg CO ₂ -eq | 4.49E-01 | 9.87E-02 | 2.10E-03 | 3.48E-01 | 0.00E+00 | 2.03E-03 | 2.00E-04 | 0.00E+00 | 4.60E-05 | -0.00E+00 |
| GWP-luluc | kg CO ₂ -eq | 2.39E-01 | 7.27E-02 | 4.77E-03 | 1.62E-01 | 0.00E+00 | 2.24E-03 | 1.80E-04 | 0.00E+00 | 9.66E-05 | -0.00E+00 |
| ODP | kg CFC ₁₁ -eq | 7.10E-06 | 1.01E-06 | 4.52E-07 | 5.64E-06 | 0.00E+00 | 3.72E-07 | 5.76E-08 | 0.00E+00 | 5.72E-09 | -0.00E+00 |
| AP | kg SO ₂ -eq | 2.80E+00 | 1.15E+00 | 2.15E-01 | 1.43E+00 | 0.00E+00 | 1.92E-01 | 8.10E-03 | 0.00E+00 | 1.20E-03 | -1.71E-01 |
| EP | kg N-eq | 1.64E+00 | 5.04E-01 | 1.84E-01 | 9.51E-01 | 0.00E+00 | 2.49E-01 | 8.37E-03 | 0.00E+00 | 1.31E-03 | -7.27E-02 |
| SFP | kg O ₃ -eq | 4.44E+01 | 1.67E+01 | 4.50E+00 | 2.31E+01 | 0.00E+00 | 6.10E+00 | 2.02E-01 | 0.00E+00 | 3.20E-02 | -1.85E+00 |
| ADP _f | MJ | 1.14E+04 | 2.02E+03 | 4.10E+02 | 8.98E+03 | 0.00E+00 | 3.03E+02 | 5.38E+01 | 0.00E+00 | 4.55E+00 | -5.97E+02 |

Disclaimer: Interpreting the Results in Module D: The values in Module D include a recognition of the benefits or impacts related to steel recovery and recycling which occur beyond the end of the product’s service life. The rate of steel recycling and related production processes will evolve over time. The results included in Module D attempt to capture future benefits, or impacts, but are based on a methodology that uses current industry-average estimates reflecting current processes.

4.2 Contribution Analysis Results

Figure 4 shows the mill-level product results (A1-A3), inclusive of the EAF steelmaking and section rolling processes, in summarized categories to identify key contributors to LCIA results. Results are presented for each LCIA impact category under study, with the following sub-categories shown as percentages of the total result:

- Energy – Electricity: Electricity consumed at the mill sites.
- Energy – Natural Gas: Natural gas consumed at the mills.
- Energy – Other: All other energy used at the mills.

- Alloy Materials: Alloy materials used as an input to the EAF steelmaking stage.
- Iron, Steel: Iron and steel inputs, including pig iron and DRI, used as an input to the EAF steelmaking stage.
- Ancillary Materials: All other materials used at the mills, including process related gases (e.g., oxygen and argon), refractories, and electrodes.
- Facility Water: All water inputs at the mills.
- Transport: All inbound transport of materials from suppliers to the mills.
- Emissions: All emissions to air and water resulting from the mills.
- Waste & Waste Transport: All waste fates and the transport of wastes from the mills.
- Packaging: Packaging materials used to package finished products leaving the mills.

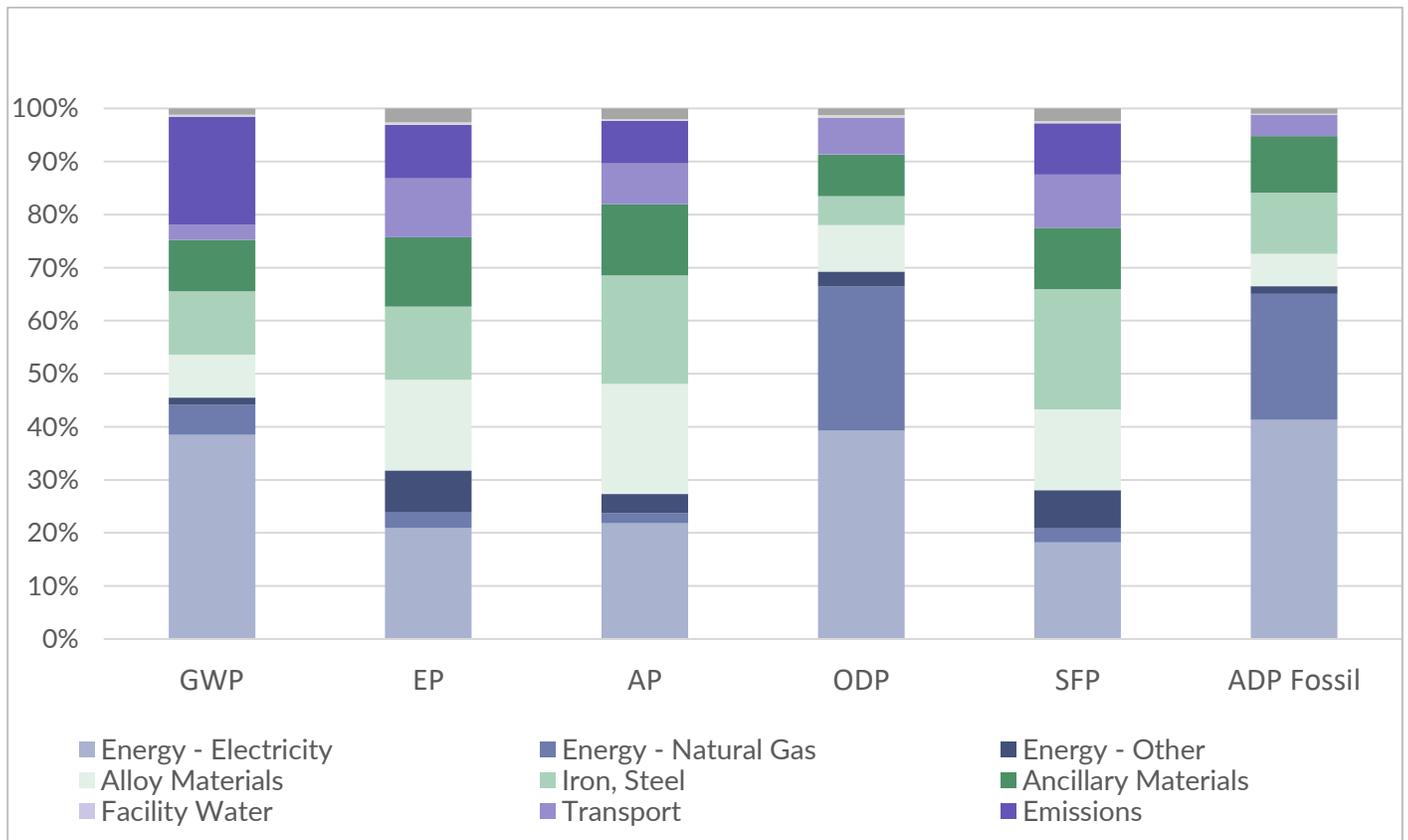


Figure 4: Contribution analysis results for production-weighted average hot-rolled structural sections (unfabricated)

Results show that electricity usage at the mill sites is the primary contributor to most impact category: 38% to GWP, 21% to EP, 22% to AP, 39% to ODP, and 39% to ADP_f. Electricity contributes 42% of the GWP impact for the EAF steelmaking process and 26% to the section rolling process. Other significant contributors to mill-level impact include natural gas consumption (ranging from 2% to AP to 27% for ODP), alloy materials (ranging from 6% to ADP_f and 21% to AP), iron and steel inputs (pig iron and DRI) (ranging from 6% to ODP to 23% to SFP), ancillary materials (ranging from 8% to ODP to 13% to EP and AP), and facility emissions (ranging from <1% to ADP_f and ODP to 20% to GWP).



4.3 Steel Product Fabrication Results

The results for the fabrication process are presented in this section. There is steel scrap, referred to as “overage” created during product fabrication; therefore, 1.0771 MT of structural steel produced at the mill sites are required to produce 1 MT of fabricated product output. Therefore, the A1 results in the tables below show a multiplier of 7.71% which is the structural steel that must be generated by the mills to account for overage. Transportation results shown in A2 reflect the transportation of 1.0771 MT of structural steel per Section 3.1.2. Table 24 through Table 27 show the industry-average LCIA impact categories, resource use, output flows and wastes, and carbon emissions and removals results for 1 metric ton of fabricated hot-rolled structural steel sections.

Table 24: LCIA results for the industry-average structural steel fabrication process to produce 1 MT of fabricated steel products

| Indicator | Unit | A1* | A2 | A3 | B1-B7 | C1 | C2 | C3 | C4 |
|------------------|--------------------------|-------|----------|----------|----------|----------|----------|----------|----------|
| GWP-total | kg CO ₂ -eq | 7.71% | 2.62E+01 | 8.24E+01 | 0.00E+00 | 2.34E+01 | 4.25E+00 | 0.00E+00 | 1.88E-01 |
| GWP-fossil | kg CO ₂ -eq | 7.71% | 2.62E+01 | 8.23E+01 | 0.00E+00 | 2.34E+01 | 4.25E+00 | 0.00E+00 | 1.88E-01 |
| GWP-biogenic | kg CO ₂ -eq | 7.71% | 1.85E-03 | 4.27E-02 | 0.00E+00 | 2.03E-03 | 2.00E-04 | 0.00E+00 | 4.60E-05 |
| GWP-luluc | kg CO ₂ -eq | 7.71% | 1.71E-03 | 5.48E-02 | 0.00E+00 | 2.24E-03 | 1.80E-04 | 0.00E+00 | 9.66E-05 |
| ODP | kg CFC ₁₁ -eq | 7.71% | 5.41E-07 | 7.72E-07 | 0.00E+00 | 3.72E-07 | 5.76E-08 | 0.00E+00 | 5.72E-09 |
| AP | kg SO ₂ -eq | 7.71% | 9.89E-02 | 2.15E-01 | 0.00E+00 | 1.92E-01 | 8.10E-03 | 0.00E+00 | 1.20E-03 |
| EP | kg N-eq | 7.71% | 1.13E-01 | 1.08E-01 | 0.00E+00 | 2.49E-01 | 8.37E-03 | 0.00E+00 | 1.31E-03 |
| SFP | kg O ₃ -eq | 7.71% | 2.77E+00 | 2.70E+00 | 0.00E+00 | 6.10E+00 | 2.02E-01 | 0.00E+00 | 3.20E-02 |
| ADP _f | MJ | 7.71% | 5.06E+02 | 1.13E+03 | 0.00E+00 | 3.03E+02 | 5.38E+01 | 0.00E+00 | 4.55E+00 |

* The % values in this column represent the additional mill material needed to account for overage generated in A3.

Table 25: Resource use results for 1 metric ton of industry-average structural steel fabrication

| Indicator | Units | A1* | A2 | A3 | B1-B7 | C1 | C2 | C3 | C4 |
|-----------|----------------|-------|----------|----------|----------|----------|----------|----------|----------|
| RPRE | MJ | 7.71% | 1.11E+00 | 1.50E+02 | 0.00E+00 | 2.88E+00 | 1.18E-01 | 0.00E+00 | 4.27E-02 |
| RPRM | MJ | 7.71% | 0.00E+00 |
| NRPRE | MJ | 7.71% | 5.03E+02 | 1.46E+03 | 0.00E+00 | 3.06E+02 | 5.36E+01 | 0.00E+00 | 4.57E+00 |
| NRPRM | MJ | 7.71% | 0.00E+00 |
| SM | kg | 7.71% | 0.00E+00 |
| RSF | MJ | 7.71% | 0.00E+00 |
| NRSF | MJ | 7.71% | 0.00E+00 |
| RE | MJ | 7.71% | 0.00E+00 |
| FW | m ³ | 7.71% | 5.51E-03 | 3.72E-01 | 0.00E+00 | 1.12E-02 | 5.90E-04 | 0.00E+00 | 2.20E-04 |

* The % values in this column represent the additional mill material needed to account for overage generated in A3.

Table 26: Waste and output results for 1 metric ton of industry-average structural steel fabrication

| Indicator | Units | A1* | A2 | A3 | B1-B7 | C1 | C2 | C3 | C4 |
|-----------|-------|-------|----------|----------|----------|----------|----------|----------|----------|
| HWD | kg | 7.71% | 3.53E-03 | 4.08E-03 | 0.00E+00 | 2.09E-03 | 3.80E-04 | 0.00E+00 | 2.91E-05 |
| NHWD | kg | 7.71% | 7.05E-02 | 1.23E+01 | 0.00E+00 | 1.96E-01 | 7.50E-03 | 0.00E+00 | 3.00E+01 |
| HLRW** | kg | 7.71% | N/A |
| ILLRW** | kg | 7.71% | N/A |
| CRU | kg | 7.71% | N/A |
| MR | kg | 7.71% | 0.00E+00 | 7.71E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 9.70E+02 |
| MER | kg | 7.71% | 0.00E+00 |
| EE | MJ | 7.71% | 0.00E+00 |

* The % values in this column represent the additional mill material needed to account for overage generated in A3.

**Data on radioactive waste disposal is not available in ecoinvent as an elementary flow. As such, impacts for HLRW and ILLRW are not reported by ACLCA guidance (ACLCA, 2018).

Table 27: Carbon emissions and removals results for 1 metric ton of industry-average structural steel fabrication

| Indicator | Units | A1 | A2 | A3 | Total |
|-----------|------------------------|-----|-----|-----|-------|
| BCRP | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| BCEP | kg CO ₂ -eq | N/A | N/A | N/A | N/A |



| Indicator | Units | A1 | A2 | A3 | Total |
|-----------|------------------------|-----|-----|-----|-------|
| BCRK | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| BCEK | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| BCEW | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| CCE | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| CCR | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| CWNR | kg CO ₂ -eq | N/A | N/A | N/A | N/A |

* Refer to Section 2.6 for discussion of carbon emissions and removals.

Results Disclaimer: It is recognized that by following the typical ISO 21930:2017 definitions of module A1, A2 and A3 for a specific production facility, inconsistencies will occur in classifying individual processes as either A1 or A3 based on the scope of the operations that take place at a given facility. Care must be taken not to compare A1, A2 or A3 on an individual basis for a given product from various mill producers, but, instead on the aggregated total of A1, A2 and A3. Separate A1, A2 and A3 values are provided for a better understanding of the processes taking place at a given facility and a greater level of transparency.

Construction product environmental impact results provide a sufficient basis for comparison only when considered in the context of the construction works project. In all cases of comparing construction products, the principle that the basis for comparison of the assessment is the construction works level shall be maintained by ensuring that the same functional requirements are met and the criteria in ISO 21930:2017 Section 5.5 “Comparability of EPDs for construction products” are satisfied.

Figure 5 shows the contribution analysis for the fabrication stage (A3) to better understand the sources and their magnitude of potential environmental impacts. The impacts are presented for the gate-to-gate fabrication process; therefore, excluding the production (A1) and transportation (A2) of structural steel to the fabricator facilities. The largest contributor to all impacts is electricity consumption (52-75%).

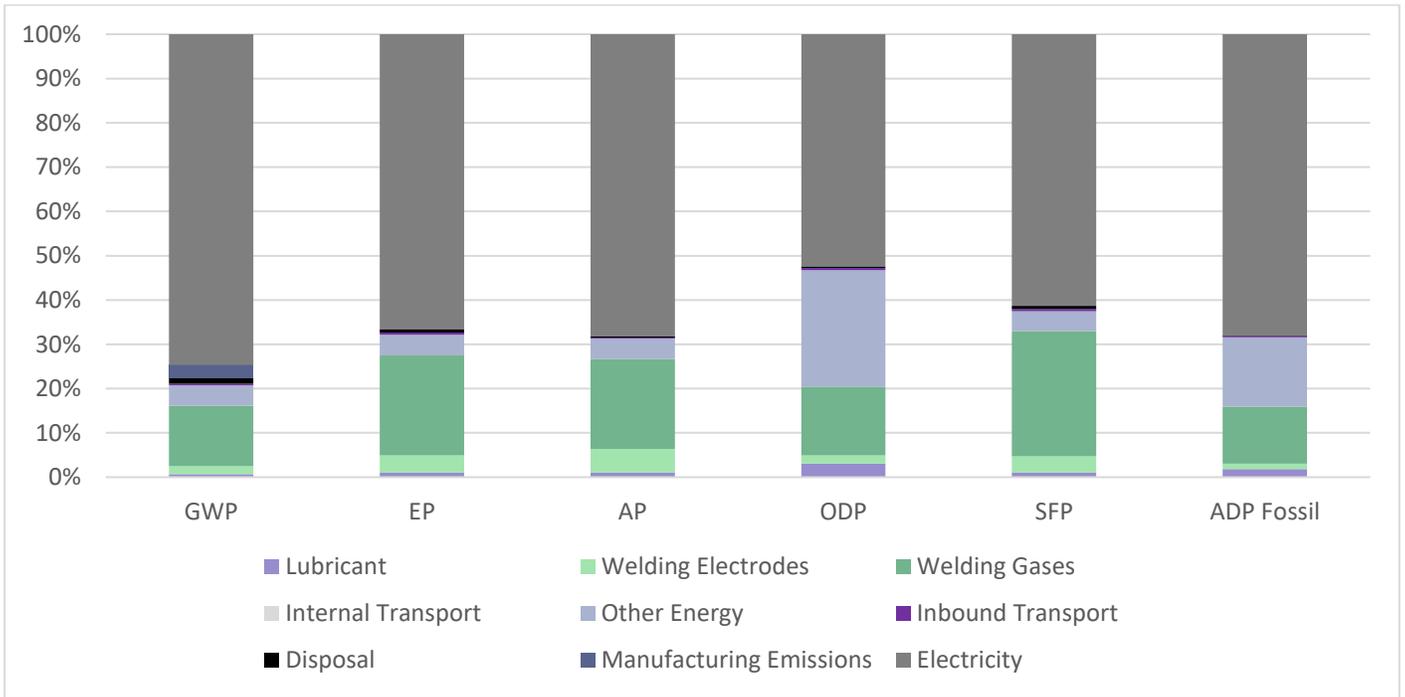


Figure 5: Contribution analysis results for the U.S. average fabrication process



4.4 Fabricated Hot-Rolled Structural Steel Sections Results

As discussed in Section 4.3, to account for steel scrap created during product fabrication, 1.0771 MT of hot-rolled structural steel sections produced at the mill sites are required to produce 1 MT of fabricated product output. Therefore, the A1 results in the tables below have been multiplied by a factor of 1.0771.

Transportation results shown in A2 also reflect the transportation of 1.0771 MT of structural steel sections.

Table 28 through Table 31 show the industry-average LCIA impact categories, resource use, output flows and wastes, and carbon emissions and removals results for 1 metric ton of fabricated hot-rolled structural steel sections.

Table 28: LCIA results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections

| Indicator | Unit | Total (A1-A3) | A1 | A2 | A3 | B1-B7 | C1 | C2 | C3 | C4 |
|------------------|--------------------------|---------------|----------|----------|----------|----------|----------|----------|----------|----------|
| GWP-total | kg CO ₂ -eq | 1.08E+03 | 9.67E+02 | 2.62E+01 | 8.24E+01 | 0.00E+00 | 2.34E+01 | 4.25E+00 | 0.00E+00 | 1.88E-01 |
| GWP-fossil | kg CO ₂ -eq | 1.08E+03 | 9.67E+02 | 2.62E+01 | 8.23E+01 | 0.00E+00 | 2.34E+01 | 4.25E+00 | 0.00E+00 | 1.88E-01 |
| GWP-biogenic | kg CO ₂ -eq | 5.28E-01 | 4.83E-01 | 1.85E-03 | 4.27E-02 | 0.00E+00 | 2.03E-03 | 2.00E-04 | 0.00E+00 | 4.60E-05 |
| GWP-luluc | kg CO ₂ -eq | 3.14E-01 | 2.57E-01 | 1.71E-03 | 5.48E-02 | 0.00E+00 | 2.24E-03 | 1.80E-04 | 0.00E+00 | 9.66E-05 |
| ODP | kg CFC ₁₁ -eq | 8.96E-06 | 7.65E-06 | 5.41E-07 | 7.72E-07 | 0.00E+00 | 3.72E-07 | 5.76E-08 | 0.00E+00 | 5.72E-09 |
| AP | kg SO ₂ -eq | 3.33E+00 | 3.02E+00 | 9.89E-02 | 2.15E-01 | 0.00E+00 | 1.92E-01 | 8.10E-03 | 0.00E+00 | 1.20E-03 |
| EP | kg N-eq | 1.99E+00 | 1.77E+00 | 1.13E-01 | 1.08E-01 | 0.00E+00 | 2.49E-01 | 8.37E-03 | 0.00E+00 | 1.31E-03 |
| SFP | kg O ₃ -eq | 5.32E+01 | 4.78E+01 | 2.77E+00 | 2.70E+00 | 0.00E+00 | 6.10E+00 | 2.02E-01 | 0.00E+00 | 3.20E-02 |
| ADP _f | MJ | 1.39E+04 | 1.23E+04 | 5.06E+02 | 1.13E+03 | 0.00E+00 | 3.03E+02 | 5.38E+01 | 0.00E+00 | 4.55E+00 |

Table 29: Resource use results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections

| Indicator | Units | Total (A1-A3) | A1 | A2 | A3 | B1-B7 | C1 | C2 | C3 | C4 |
|-----------|-------|---------------|----------|----------|----------|----------|----------|----------|----------|----------|
| RPRE | MJ | 2.01E+03 | 1.86E+03 | 1.11E+00 | 1.50E+02 | 0.00E+00 | 2.88E+00 | 1.18E-01 | 0.00E+00 | 4.27E-02 |
| RPRM | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NRPRES | MJ | 1.58E+04 | 1.38E+04 | 5.03E+02 | 1.46E+03 | 0.00E+00 | 3.06E+02 | 5.36E+01 | 0.00E+00 | 4.57E+00 |
| NRPRM | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| SM | kg | 1.07E+03 | 1.07E+03 | 0.00E+00 |
| RSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| NRSF | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| RE | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FW | m3 | 4.07E+00 | 3.69E+00 | 5.51E-03 | 3.72E-01 | 0.00E+00 | 1.12E-02 | 5.90E-04 | 0.00E+00 | 2.20E-04 |

Table 30: Waste and output results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections

| Indicator | Units | Total (A1-A3) | A1 | A2 | A3 | B1-B7 | C1 | C2 | C3 | C4 |
|-----------|-------|---------------|----------|----------|----------|----------|----------|----------|----------|----------|
| HWD | kg | 3.95E-02 | 3.19E-02 | 3.53E-03 | 4.08E-03 | 3.19E-02 | 2.09E-03 | 3.80E-04 | 0.00E+00 | 2.91E-05 |
| NHWD | kg | 1.84E+01 | 6.02E+00 | 7.05E-02 | 1.23E+01 | 6.02E+00 | 1.96E-01 | 7.50E-03 | 0.00E+00 | 3.00E+01 |
| HLRW* | kg | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| ILLRW* | kg | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| CRU | kg | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| MR | kg | 1.38E+02 | 6.04E+01 | 0.00E+00 | 7.71E+01 | 6.04E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 9.70E+02 |
| MER | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| EE | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

*Data on radioactive waste disposal is not available in ecoinvent as an elementary flow. As such, impacts for HLRW and ILLRW are not reported by ACLCA guidance (ACLCA, 2018).

Table 31: Carbon emissions and removals results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections

| Indicator | Units | A1 | A2 | A3 | Total |
|-----------|------------------------|-----|-----|-----|-------|
| BCRP | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| BCEP | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| BCRK | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| BCEK | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| BCEW | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| CCE | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| CCR | kg CO ₂ -eq | N/A | N/A | N/A | N/A |
| CWNR | kg CO ₂ -eq | N/A | N/A | N/A | N/A |

* Refer to Section 2.6 for discussion of carbon emissions and removals.

Results Disclaimer: It is recognized that by following the typical ISO 21930:2017 definitions of module A1, A2 and A3 for a specific production facility, inconsistencies will occur in classifying individual processes as either A1 or A3 based on the scope of the operations that take place at a given facility. Care must be taken not to compare A1, A2 or A3 on an individual basis for a given product from various mill producers, but, instead on the aggregated total of A1, A2 and A3. Separate A1, A2 and A3 values are provided for a better understanding of the processes taking place at a given facility and a greater level of transparency.

Construction product environmental impact results provide a sufficient basis for comparison only when considered in the context of the construction works project. In all cases of comparing construction products, the principle that the basis for comparison of the assessment is the construction works level shall be maintained by ensuring that the same functional requirements are met and the criteria in ISO 21930:2017 Section 5.5 “Comparability of EPDs for construction products” are satisfied.

The reported fabricated product results are based on industry-average fabrication impacts. Actual impacts for fabricated products vary depending on the particular project and its fabrication demands.

EPDs published using this PCR do not include post-fabrication processes, including, but not limited to, epoxy coating, painting, and galvanization.

Figure 6 shows the industry-average GWP result, per 1 metric ton of fabricated hot-rolled structural steel sections with average fabrication. Mill site results (A1) covers the EAF and section rolling processes. Table 32 shows the GWP results in Figure 6 in tabular format.

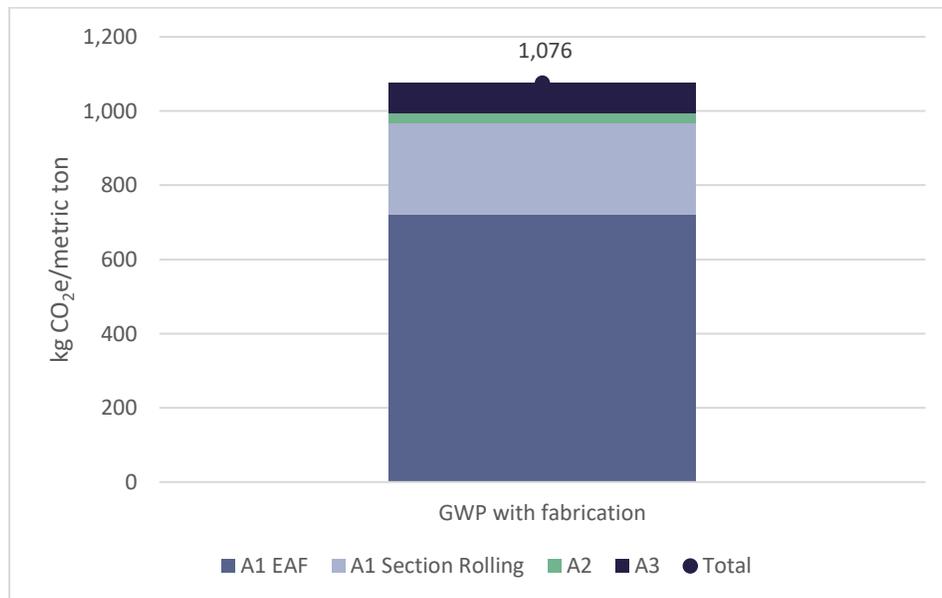


Figure 6: GWP results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections with average fabrication impacts

Table 32: GWP results for 1 metric ton of industry-average fabricated hot-rolled structural steel sections with average, 90th percentile, and 10th percentile fabrication impacts

| Product | A1 EAF | A1 Section Rolling | A2 | A3 | Total (kgCO ₂ -eq/MT) |
|---|--------|--------------------|----|-----|----------------------------------|
| Average product - Average fabrication | 721 | 246 | 26 | 82 | 1,076 |
| Average product – 90 th percentile fabrication | 721 | 246 | 28 | 256 | 1,251 |
| Average product – 10 th percentile fabrication | 721 | 246 | 28 | 29 | 1,024 |

Results show that the A1 stage, specifically the EAF process at the mill sites, contributes most significantly to the overall cradle-to-mill-gate industry-average results for fabricated hot-rolled structural steel sections.

4.5 Statistics

In accordance with PCR requirements (Smart EPD Part B Section 5.3), Table 33 below shows the minimum, maximum, mean, and median values for each LCIA impact category. These values represent the span of data for aggregated A1-A3 results for unfabricated, hot-rolled structural steel sections production. Statistical results were calculated using the Smart EPD Part B Annex C template.

Table 33: Statistical metrics for 1 metric ton of hot-rolled structural steel sections (A1-A3) across all facilities

| Indicator | Unit | Samples | Weighted Mean | Weighted St. Dev.* | Min | Max |
|-----------|-------------------------|---------|---------------|--------------------|----------|----------|
| GWP | kg CO ₂ -eq. | 6 | 8.98E+02 | 2.01E+02 | 6.32E+02 | 1.24E+03 |
| EP | kg N-eq. | 6 | 1.64E+00 | 5.00E-01 | 1.01E+00 | 2.57E+00 |
| AP | kg SO ₂ -eq. | 6 | 2.80E+00 | 1.24E+00 | 1.47E+00 | 5.73E+00 |
| ODP | kg CFC 11-eq. | 6 | 7.10E-06 | 1.28E-06 | 5.18E-06 | 8.54E-06 |
| SFP | kg O ₃ -eq. | 6 | 4.44E+01 | 2.24E+01 | 2.43E+01 | 9.83E+01 |

* Note that this is a representational statistic indicating the scale of variation. It is not a true standard deviation due to the potentially low number of samples. The calculation uses the frequency weighted sample variance formula.

4.6 Sensitivity Analysis

4.6.1 Allocation Sensitivity

At the mill sites in the EAF process, slag is produced and sold for beneficial use. As discussed in Section 2.5.2, co-product allocation has been performed to assign a share of the steelmaking burden to the slag from each input and output. This sensitivity analysis was conducted in order to understand the potential difference in impact results if no burden were given to the slag, i.e., if all burden were allocated to the steel product. This analysis is also a requirement in (ISO, 2006b) Section 4.3.4.1, where more than one allocation procedure may be applicable.

Table 34 below provides the LCIA results for the mill product (A1) if no allocation to the slag co-product occurred.

Table 34: LCIA results for 1 metric ton of fabricated hot-rolled structural steel sections, with no burden assigned to slag co-product

| Indicator | Unit | A1 | A2 | A3 | Total |
|-----------|------------------------|----------|----------|----------|----------|
| GWP | kg CO ₂ eq. | 1.05E+03 | 2.62E+01 | 8.24E+01 | 1.16E+03 |
| EP | kg N eq. | 1.91E+00 | 1.13E-01 | 1.08E-01 | 2.13E+00 |
| AP | kg SO ₂ eq. | 3.24E+00 | 9.89E-02 | 2.15E-01 | 3.56E+00 |
| ODP | kg CFC 11 eq. | 8.36E-06 | 5.41E-07 | 7.72E-07 | 9.67E-06 |
| SFP | kg O ₃ eq. | 5.15E+01 | 2.77E+00 | 2.70E+00 | 5.70E+01 |

| Indicator | Unit | A1 | A2 | A3 | Total |
|------------------|------|----------|----------|----------|----------|
| ADP _f | MJ | 1.35E+04 | 5.06E+02 | 1.13E+03 | 1.51E+04 |

Table 35 shows the burden assigned to slag, first in terms of slag burden per MT steel, representing the difference between results with and without slag allocation, and secondly per kg slag produced. The production weighted slag output per 1 metric ton of steel was 146 kg.

Table 35: LCIA results showing allocation burden assigned to slag

| Indicator | Unit | Allocation to Slag (per MT steel) | Allocation to Slag (per kg slag) |
|------------------|-------------------------|-----------------------------------|----------------------------------|
| GWP | kg CO ₂ -eq. | 8.07E+01 | 5.53E-01 |
| EP | kg N-eq. | 1.33E-01 | 9.12E-04 |
| AP | kg SO ₂ -eq. | 2.10E-01 | 1.44E-03 |
| ODP | kg CFC 11-eq. | 6.54E-07 | 4.49E-09 |
| SFP | kg O ₃ -eq. | 3.39E+00 | 2.32E-02 |
| ADP _f | MJ | 1.13E+03 | 7.73E+00 |

Figure 7 shows the percentage difference between the base case A1 (without fabrication) results with physical partitioning allocation to slag applied and the scenario case A1 (without fabrication) excluding co-product allocation. Results are shown as a percentage of the base case.

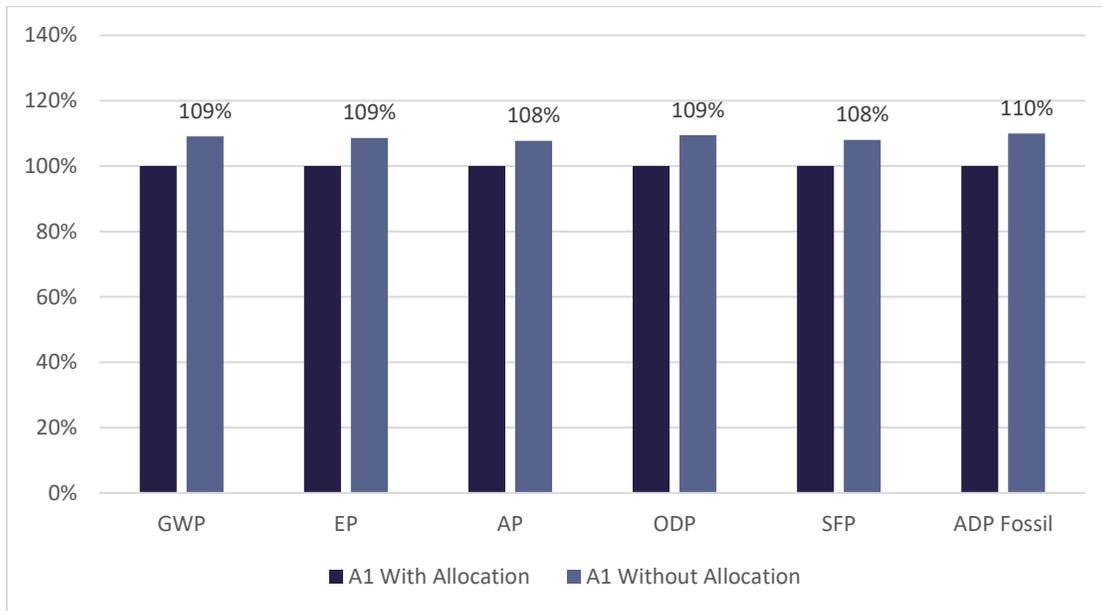


Figure 7: LCIA results of the baseline case (allocation to slag co-product) and scenario case (no co-product allocation), shown as percent of baseline

Results of the scenario analysis show that when no burden is allocated to the slag co-product, the LCIA results increase across all indicators. An overall increase of 8% to 10% is observed across all categories.

4.6.2 Electricity Source Sensitivity

As renewable contractual instruments were included in the baseline results, a sensitivity analysis was conducted to assess the impact of excluding the unbundled RECs from the system assuming electricity is instead supplied 100% from the grid. This section reports the non-adjusted baseline results in accordance

with Part B PCR requirements. The dedicated on-site solar facility at a separate mill remains part of the baseline and non-adjusted baseline results.

Table 36 presents the LCIA results for 1 metric ton of industry-average hot-rolled structural steel sections modeled without RECs, broken down by modules A1 through A3. Since the results for other modules remain unchanged, only A1–A3 results are shown. The use of renewable energy through purchased RECs resulted in a 0.8% reduction in the A1–A3 GWP-total impacts of the U.S.-average production of hot-rolled structural steel sections.

Table 36: LCIA results for 1 metric ton of industry-average hot-rolled structural steel sections- without RECs

| Impact Category | Units | Total (A1-A3) | A1 | A2 | A3 |
|------------------------|---------------------------|---------------|----------|----------|----------|
| GWP-total | kg CO ₂ -eq. | 9.06E+02 | 1.79E+02 | 2.78E+01 | 6.99E+02 |
| GWP-fossil | kg CO ₂ -eq. | 9.05E+02 | 1.79E+02 | 2.78E+01 | 6.99E+02 |
| GWP-biogenic | kg CO ₂ -eq. | 4.50E-01 | 9.87E-02 | 2.10E-03 | 3.49E-01 |
| GWP-luluc | kg CO ₂ -eq. | 2.38E-01 | 7.27E-02 | 4.77E-03 | 1.61E-01 |
| ODP | kg CFC ₁₁ -eq. | 1.65E+00 | 5.04E-01 | 1.84E-01 | 9.59E-01 |
| AP | kg SO ₂ -eq. | 2.82E+00 | 1.15E+00 | 2.15E-01 | 1.45E+00 |
| EP | kg N-eq. | 7.12E-06 | 1.01E-06 | 4.52E-07 | 5.66E-06 |
| SFP | kg O ₃ -eq. | 4.45E+01 | 1.67E+01 | 4.50E+00 | 2.33E+01 |
| ADP_r | MJ | 1.15E+04 | 2.02E+03 | 4.10E+02 | 9.07E+03 |

5 Interpretation

5.1 Identification of Relevant Findings

For industry average results excluding fabrication, A3 (steelmaking) was the largest contributor to impact, amounting to 77% of the total GWP and 51-79% for all other impact categories. Transportation of feedstock materials to the mills was only a minor contributor, ranging from 3-11% for all impact categories. Within the mill sites, the EAF steelmaking process is the largest contributor, representing 75% of the overall GWP results. It is also the most significant contributor to all other impacts (69% - 86%). Electricity usage at the mills represents the highest contribution to each LCIA impact category, ranging from 18% - 41% of the overall A1-A3 impacts and contributing 38% of the GWP impact. On a unit process basis, electricity contributes 42% to the EAF steelmaking process GWP and 26% to the section rolling process GWP. Site emissions, mainly CO₂, contributed 20% of the A1-A3 GWP impacts. Aside from electricity, the key contributors to EP were alloy materials (17%) and iron and steel inputs (14%); to AP were alloy materials (21%) and iron and steel inputs (20%); to SFP were iron and steel inputs (23%), alloy materials (15%), and ancillary materials (11%); and to ADP_f was natural gas (24%).

When fabrication is included, the LCA results indicate that the A1 stage (steelmaking) is the most significant contributor to overall results, representing 90% of the cradle-to-fabricator-gate GWP footprint. It represents 85-91% of the results for all other categories. The A2 stage is a minor contributor, representing 2.4% of overall GWP results, largely due to the significant share of rail transport. The A3 stage is also a relatively minor contributor, representing 7.7% of overall cradle-to-fabricator-gate GWP footprint.

Within A2 (transport from mills to fabricators), though it makes up only 25% of the total transport distance, transporting hot-rolled structural steel sections from the mills to fabrication sites by truck contributes 87% of the GWP impacts. Truck transportation contributes 41-57% to all other impacts in this study.

For the A3 stage representing the fabrication process, the largest contributor to all results categories is electricity, ranging from 52-75%. Welding gases are also significant contributors to all impacts (up to 28%) and other energy consumed at the sites is significant for ODP and ADP_f.

5.2 Conclusions, Limitations, and Recommendations

The goal of this study was to quantify the potential environmental impacts of industry-average hot-rolled structural steel sections produced by AISC's members in the U.S. to support the preparation of an updated industry-average EPD. The LCIA results were assessed relative to the production of one metric ton of hot-rolled structural steel sections. ISO 14040, ISO 14044, ISO 21930, Smart EPD's PCR Part A: Product Category Rules for Building and Construction Products and Services, and Smart EPD's PCR Part B: Product Category Rules for Designated Steel Construction Products were used as the basis for calculation and reporting of the environmental impacts.

The results of the LCIA indicate that the potential environmental impacts for fabricated hot-rolled structural steel sections produced in the U.S. are driven by the steelmaking process at the mills, with virgin iron inputs, electricity usage, and alloying materials contributing most significantly to impact.

The study included the physical partitioning approach to allocate burden to slag produced as a co-product alongside steel production. Results of the scenario analysis showed that if no burden is allocated to slag, LCIA results increased by 8-10%.

5.2.1 Limitations

The results are limited to the specific processes and materials under study, at EAF steelmaking and fabrication sites located in the U.S., and more general conclusions about hot-rolled structural steel sections produced in other regions, other structural steel products, and fabrication processes outside of the U.S. may not be drawn. Additionally, individual site results should not be assumed from the average results. When reviewing the results, care should be taken to consider potential trade-offs between impact categories, particularly if the results are used to inform future product or process development.

The study aimed to establish a full picture of potential environmental impacts; however, it does not consider human or ecological toxicity or other impacts outside of those explicitly discussed in this report. The study is limited to the environmental impacts of fabricated hot-rolled structural steel sections and does not account for downstream life cycle stages or specific uses of the product.

Data quality and limitations pertaining to data and analysis assumptions are discussed in Section 3.3.

Required note per the Smart EPD Part B PCR: A collection of manufacturer-average and/or facility-specific EPDs is insufficient for setting benchmarks and thresholds unless production volumes are taken into account. Benchmarking and threshold setting efforts shall also consider that some manufacturer-average data and facility-specific data may be represented in Industry-average EPDs and may result in double counting of the same data.

5.2.2 Recommendations

Pig iron and DRI were key contributors to overall results, even though they comprised a relatively small share of the overall raw materials used in steelmaking on average. DRI was modeled using primary data. Pig iron was modeled with RoW average data representing conventional pig iron production from ecoinvent v3.10. A share of the pig iron consumed in 2023 is produced using charcoal with a subset derived from sustainably managed biochar. A reduction in impact could be seen with more differentiation of pig iron by type, if data were made available. In addition, minimizing the amount of both virgin iron and alloying element inputs could reduce environmental impacts.

Electricity was the most significant contributor to impact for both the steelmaking and fabrication processes. On-site renewable energy systems and purchased high-quality renewable electricity contractual instruments that meet the Smart EPD PCR Part A and Part B requirements could reduce environmental impacts.

As stated in Section 3.1, not all mill sites provided complete emissions data for fuels combusted at their sites. Therefore, combustion was modeled with fuel datasets including production and combustion of the fuels. A recommendation for the future of the study is to request and support sites in providing complete and consistent emissions data.

References

- ACLCA. (2018). *ACLCA Guidance to Calculating Non-LCIA Inventory Metrics in Accordance with ISO 21930: 2017*.
- AISI. (2021). *Life Cycle Inventories of North American Steel Products*.
- American Iron and Steel Institute. (2020). *Life Cycle Inventories of North American Steel Products*.
- ANSI/AISC 303-22. (2022). *Code of Standard Practice for Steel Buildings and Bridges*. Retrieved from <https://www.aisc.org/globalassets/aisc/publications/standards/a303-22w.pdf>
- Aufhauser. (n.d). *Safety Data Sheet*. Retrieved from <https://www.brazing.com/Pdf/MSDS/New-SDS-MildSteelFluxCore.pdf>
- Bare, J. (2011). TRACI - The Tool for the Reduction and Assessment of Chemical and other Environmental Impacts. *CLEAN TECHNOLOGIES AND ENVIRONMENTAL POLICY*.
- Colorado Office of the State Architect. (2025). *MasterFormat CSI Code Sections*. Retrieved from <https://osa.colorado.gov/masterformat-csi-code-sections>
- EPA. (2023). *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM), Background Chapters (EPA-530-R-23-017)*. Washington, DC: U.S. Government Printing Office. Retrieved from https://www.epa.gov/system/files/documents/2023-12/warm-background_v16_dec.pdf
- European Commission. (2022). *Environmental Footprint (EF) reference package 3.1*. Retrieved from <https://eplca.jrc.ec.europa.eu/LCDN/developerEF.html>
- European Standards. (2012). *EN 15804 - 2012 Sustainability of construction works, Environmental product declarations, Core rules for the product category of construction products*.
- Federal LCA Commons. (2024). *National Renewable Energy Laboratory/US LCI*. Retrieved from https://www.lcacommons.gov/lca-collaboration/National_Renewable_Energy_Laboratory/USLCI_Database_Public/datasets/Processes/48-49:%20Transportation%20and%20Warehousing
- Guinée, J.B. et al. (2002). *Handbook on life cycle assessment. Operational guide to the ISO standards. I: LCA in perspective. IIa: Guide. IIb: Operational annex. III: Scientific background*. Dordrecht: Kluwer Academic Publishers.
- IEA. (n.d.). *Brazil*. Retrieved from <https://www.iea.org/countries/brazil>
- IPCC. (2021). *Climate Change 2021: The Physical Science Basis*. IPCC.
- ISO. (2006a). *14040:2006/Amd.1:2020 – Environmental management – Life cycle assessment – Principles and framework*. Geneva: International Organization of Standardization.
- ISO. (2006b). *14044:2006/Amd.1:2017/Amd.2:2020 – Environmental management – Life cycle assessment – Requirements and guidelines*. Geneva: International Organization for Standardization.

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

Pinnacle Alloys. (2022). *Safety Data Sheet*. Retrieved from <https://www.pinnaclealloys.com/wp/wp-content/uploads/2015/11/A5.28.pdf>

Pinnacle Alloys. (2022). *Safety Data Sheet (SDS)*. Retrieved from <https://www.pinnaclealloys.com/wp/wp-content/uploads/2015/11/A5.17-A5.23-11.4.19.pdf>

Siebers, R. W. (2020). *Recording sustainability indicators for the value chain - construction and demolition in steel construction [Ph.D. Thesis]*. University of Wuppertal.

Smart EPD. (2025a, March). *Smart EPD Part A Product Category Rules for Building and Construction Products and Services, Standard 1000. Version 1.2*. Retrieved from www.smartepd.com

Smart EPD. (2025b, April 3). *Smart EPD Part B Product Category Rules for Designated Steel Construction Products. Version 3.0. Standard 1000-008*. Retrieved from www.smartepd.com

Sphera. (2021). *EPD Background Report: Fabricated hot-rolled sections and plates*.

The World Steel Association. (2014). *A methodology to determine the LCI of steel industry co-products*.

United States Environment Protection Agency. (2025). *Detailed Data: eGRID with 2023 Data*. Retrieved from <https://www.epa.gov/egrid/detailed-data>

Washington Alloy. (2023). *Carbon Steel Electrodes*. Retrieved from <https://www.washingtonalloy.com/wp-content/uploads/2023/07/CARBON-STEELELECTRODES-2023.pdf>

Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., & Weidema, B. (2016). The ecoinvent database version 3 (part I): overview and methodology. *The International Journal of Life Cycle Assessment*, 1218-1230.

World Steel Association. (2014). *A methodology to determine the LCI of steel industry co-products*. World Steel Association.

World Steel Association. (2025). *LCI Data for Steel Products*.

Annex A: Unit Processes

Table 37: Complete unit process for 1 metric ton of the industry-average EAF process

| Material | Amount | Units |
|---|----------|-------|
| Inputs – Raw Materials | | |
| DRI | 3.96E-02 | MT |
| Pig Iron | 2.92E-02 | MT |
| External Scrap | 9.93E-01 | MT |
| Home Scrap | 6.76E-02 | MT |
| Internal Scrap | 1.35E-02 | MT |
| Aluminum | 2.57E-05 | MT |
| Aluminum Oxide | 1.82E-05 | MT |
| Calcium Silicide | 5.90E-05 | MT |
| Columbium | 2.96E-05 | MT |
| Copper | 7.19E-06 | MT |
| Ferro Boron | 1.09E-07 | MT |
| Ferro Chromium | 1.31E-04 | MT |
| Ferro Manganese | 3.66E-04 | MT |
| Ferro Molybdenum | 1.26E-05 | MT |
| Ferro Niobium | 3.38E-05 | MT |
| Ferro Silicon | 1.23E-03 | MT |
| Fluorspar | 9.18E-04 | MT |
| Iron Phosphide | 2.20E-06 | MT |
| Iron Silicide | 3.07E-04 | MT |
| Molybdenum Oxide | 1.55E-05 | MT |
| Nickel | 9.67E-05 | MT |
| Phosphorous | 4.50E-06 | MT |
| Silicomanganese | 1.28E-02 | MT |
| Silicon Carbide | 3.74E-06 | MT |
| Sulfur | 4.94E-06 | MT |
| Titanium | 6.02E-07 | MT |
| Vanadium | 2.38E-04 | MT |
| Vanadium Nitrite | 1.16E-05 | MT |
| Inputs – Ancillary and Process Materials | | |
| Acetylene | 1.09E-09 | MT |
| Al Wire | 1.35E-06 | MT |
| Anthracite | 1.95E-03 | MT |
| Argon Gas | 1.06E-03 | MT |
| Argon Gas Produced On-Site | 2.36E-04 | MT |
| C wire | 1.12E-05 | MT |
| Ca Wire | 8.45E-07 | MT |
| Calcium | 3.75E-05 | MT |
| Calcium Carbide | 1.42E-04 | MT |
| CaSi Wire | 1.69E-07 | MT |
| CaSISIC Cored Wire | 2.97E-06 | MT |
| Charge Carbon | 5.62E-04 | MT |
| Coke | 3.28E-03 | MT |
| Dolomite | 1.46E-02 | MT |
| Graphite | 2.18E-04 | MT |
| Graphite Electrodes | 1.79E-03 | MT |
| Injection Carbon | 1.32E-02 | MT |
| Ladle Carbon | 9.21E-07 | MT |
| Lime | 2.95E-02 | MT |



| Material | Amount | Units |
|--|----------|-------|
| Nitrogen Gas | 1.13E-02 | MT |
| Oils & Lubricants | 6.94E-05 | MT |
| Oxygen Gas | 4.84E-02 | MT |
| Oxygen Gas Produced On-Site | 1.24E-02 | MT |
| Quick Lime | 2.11E-03 | MT |
| Refractory | 3.40E-03 | MT |
| S wire | 0.00E+00 | MT |
| Samplers | 1.26E-05 | MT |
| Sand | 3.01E-04 | MT |
| Inputs - Energy | | |
| Electricity Generated On-site | 1.01E+01 | kWh |
| Purchased Electricity | 5.54E+02 | kWh |
| Natural Gas | 5.93E+02 | MJ |
| Natural Gas Combusted | 9.01E+01 | MJ |
| Diesel | 5.49E+01 | MJ |
| Gasoline | 2.32E+00 | MJ |
| Propane | 7.99E-01 | MJ |
| Inputs - Water | | |
| Ground Water | 8.93E-01 | m3 |
| Municipal Water | 2.11E-01 | m3 |
| Surface Water | 1.21E-02 | m3 |
| Inputs - Transportation | | |
| Inbound Barge | 2.29E+01 | MT.km |
| Inbound Rail | 2.96E+02 | MT.km |
| Inbound Ship | 6.70E+02 | MT.km |
| Inbound Truck | 1.67E+02 | MT.km |
| Outputs - Product & Co-Products | | |
| Product Output (Steel Blooms) | 1.00E+00 | MT |
| Internal Scrap | 1.35E-02 | MT |
| Mill Scale | 1.28E-02 | MT |
| Slag | 1.46E-01 | MT |
| Outputs - Water | | |
| Wastewater POTW | 3.91E-02 | m3 |
| Water Discharged | 7.06E-02 | m3 |
| Water Emissions to Air | 1.01E+00 | m3 |
| Outputs - Emissions to Air | | |
| 1,3-Butadiene | 3.77E-07 | MT |
| 1,4-Dichlorobenzene | 9.51E-11 | MT |
| 2-Methylnaphthalene | 1.91E-12 | MT |
| Acetaldehyde | 7.46E-08 | MT |
| Acrolein | 3.04E-08 | MT |
| Aluminum Oxide | 7.31E-08 | MT |
| Ammonia | 2.46E-07 | MT |
| Antimony | 4.23E-09 | MT |
| Arsenic | 9.96E-10 | MT |
| Benzene | 5.54E-09 | MT |
| Beryllium | 5.15E-14 | MT |
| Cadmium | 2.57E-09 | MT |
| Calcium Oxide | 6.42E-07 | MT |
| Carbon Dioxide | 7.91E-02 | MT |
| Carbon Disulfide | 3.89E-08 | MT |
| Carbon Monoxide | 6.15E-04 | MT |
| Carbon Tetrachloride | 3.51E-09 | MT |
| Chlorine | 1.20E-08 | MT |
| Chloroform | 1.02E-08 | MT |
| Chromium | 8.27E-09 | MT |
| Copper Oxide | 1.57E-08 | MT |



| Material | Amount | Units |
|--|----------|-------|
| Ethane | 2.73E-07 | MT |
| Ethyl Benzene | 2.45E-09 | MT |
| Fluorides | 1.41E-08 | MT |
| Fluorine | 6.77E-07 | MT |
| Formaldehyde | 2.87E-08 | MT |
| HAPs | 1.69E-07 | MT |
| Hydrochloric Acid | 3.45E-11 | MT |
| Hydrogen Fluoride | 4.25E-08 | MT |
| Iron Oxide | 3.66E-07 | MT |
| Lead | 8.75E-08 | MT |
| Lead Oxide | 5.76E-08 | MT |
| Magnesium Oxide | 4.27E-07 | MT |
| Manganese Oxide | 1.08E-07 | MT |
| Manganese | 3.76E-07 | MT |
| Mercury | 5.24E-08 | MT |
| Methane | 7.29E-08 | MT |
| Methanol | 4.22E-08 | MT |
| Methyl Chloride | 5.85E-09 | MT |
| Methyl Ethyl Ketone | 5.12E-08 | MT |
| Methyl Isobutyl Ketone | 2.45E-09 | MT |
| Naphthalene | 2.57E-09 | MT |
| Nickel | 2.93E-09 | MT |
| Nitrogen Dioxide | 4.62E-11 | MT |
| Nitrous Oxide | 8.35E-05 | MT |
| PAH | 2.89E-11 | MT |
| PM10 | 4.48E-05 | MT |
| PM25 | 2.05E-05 | MT |
| Styrene | 2.02E-09 | MT |
| Sulfur Dioxide | 6.58E-05 | MT |
| Sulfuric Acid | 1.61E-10 | MT |
| Toluene | 1.73E-08 | MT |
| Trichloroethylene | 2.35E-09 | MT |
| VOC | 3.56E-05 | MT |
| Zinc Oxide | 1.06E-06 | MT |
| Outputs – Emissions to Water | | |
| Barium | 9.98E-10 | MT |
| Chromium | 2.03E-09 | MT |
| Copper | 4.19E-09 | MT |
| Iron | 8.66E-15 | MT |
| Lead | 1.16E-10 | MT |
| Lithium Carbonate | 3.85E-09 | MT |
| Manganese | 1.46E-09 | MT |
| Nickel | 5.55E-08 | MT |
| Suspended Soils | 1.71E-06 | MT |
| Zinc | 6.74E-13 | MT |
| Outputs – Wastes and Materials for Recovery | | |
| Haz Waste Incineration | 1.14E-03 | MT |
| Haz Waste Landfill | 1.28E-04 | MT |
| Non Haz Waste Landfill | 6.40E-03 | MT |
| Recycled Waste | 2.22E-02 | MT |
| Sludge Solidification | 4.85E-04 | MT |
| Outputs – Transportation | | |
| Outbound Rail | 2.96E+00 | MT.km |
| Outbound Truck | 9.36E+00 | MT.km |

Table 38: Complete unit process for 1 metric ton of the industry-average structural section rolling process

| Material | Amount | Units |
|---|----------|-------|
| Inputs - Materials | | |
| Steel Blooms | 1.06E+00 | MT |
| Oils & Lubricants | 2.60E-03 | MT |
| Refractory | 1.83E-04 | MT |
| Inputs - Energy | | |
| Electricity Generated On-site | 1.69E+00 | kWh |
| Purchased Electricity | 1.13E+02 | kWh |
| Natural Gas | 1.65E+03 | MJ |
| Natural Gas Combusted | 2.27E+02 | MJ |
| Diesel | 6.60E+01 | MJ |
| Gasoline | 3.27E+00 | MJ |
| Propane | 8.41E-01 | MJ |
| Inputs - Water | | |
| Ground Water | 5.43E-01 | m3 |
| Municipal Water | 1.49E-01 | m3 |
| Surface Water | 7.90E-03 | m3 |
| Inputs - Transportation | | |
| Inbound Rail | 1.06E+00 | MT.km |
| Inbound Truck | 2.25E+01 | MT.km |
| Outputs – Product & Packaging | | |
| Product Output (Hot-rolled Structural Steel Sections) | 1.00E+00 | MT |
| Internal Scrap | 5.61E-02 | MT |
| Dunnage | 5.08E-02 | MT |
| Steel Banding | 1.21E-03 | MT |
| VCI Bag | 5.86E-07 | MT |
| Outputs - Water | | |
| Wastewater POTW | 3.38E-02 | m3 |
| Water Discharged | 5.10E-02 | m3 |
| Water Emissions to Air | 6.16E-01 | m3 |
| Outputs – Emissions to Air | | |
| 1,3-Butadiene | 3.43E-07 | MT |
| 1,4-Dichlorobenzene | 8.67E-11 | MT |
| 2-Methylnaphthalene | 1.74E-12 | MT |
| Acetaldehyde | 6.79E-08 | MT |
| Acrolein | 2.77E-08 | MT |
| Ammonia | 2.24E-07 | MT |
| Benzene | 5.05E-09 | MT |
| Carbon Dioxide | 1.09E-01 | MT |
| Carbon Disulfide | 3.54E-08 | MT |
| Carbon Monoxide | 1.10E-04 | MT |
| Carbon Tetrachloride | 3.20E-09 | MT |
| Chlorine | 1.10E-08 | MT |
| Chloroform | 9.25E-09 | MT |
| Ethane | 2.48E-07 | MT |
| Ethyl Benzene | 2.23E-09 | MT |
| Fluorides | 1.28E-08 | MT |
| Formaldehyde | 2.62E-08 | MT |
| Hydrochloric Acid | 3.14E-11 | MT |
| Hydrogen Fluoride | 3.87E-08 | MT |
| Lead Oxide | 4.00E-11 | MT |
| Methane | 8.87E-08 | MT |
| Methanol | 3.85E-08 | MT |
| Methyl Chloride | 5.33E-09 | MT |
| Methyl Ethyl Ketone | 4.67E-08 | MT |



| Material | Amount | Units |
|--|----------|-------|
| Methyl Isobutyl Ketone | 2.23E-09 | MT |
| Naphthalene | 2.34E-09 | MT |
| Nitrous Oxide | 8.53E-05 | MT |
| PAH | 5.69E-14 | MT |
| PM10 | 3.06E-05 | MT |
| PM25 | 9.65E-06 | MT |
| Styrene | 1.84E-09 | MT |
| Sulfur Dioxide | 5.00E-05 | MT |
| Sulfuric Acid | 1.47E-10 | MT |
| Toluene | 1.58E-08 | MT |
| Trichloroethylene | 2.14E-09 | MT |
| VOC | 3.01E-05 | MT |
| Outputs – Emissions to Water | | |
| Barium | 5.48E-10 | MT |
| Chromium | 1.12E-09 | MT |
| Copper | 6.31E-09 | MT |
| Iron | 1.13E-14 | MT |
| Lead | 1.14E-10 | MT |
| Lithium Carbonate | 8.05E-10 | MT |
| Manganese | 3.05E-08 | MT |
| Nickel | 2.12E-09 | MT |
| Suspended Soils | 9.37E-07 | MT |
| Zinc | 4.18E-09 | MT |
| Outputs – Wastes and Materials for Recovery | | |
| Haz Waste Incineration | 1.13E-07 | MT |
| Haz Waste Landfill | 1.44E-04 | MT |
| Non Haz Waste Landfill | 6.59E-03 | MT |
| Sludge Solidification | 3.24E-04 | MT |
| Outbound Truck | 3.13E+00 | MT.km |

Annex B: Background Data

Table 39: Key process data source reporting, from Smart EPD’s Part B PCR, Table D-1

| Input / Unit Process | Origin of Material or Process | LCI data source reference |
|---|-------------------------------|---|
| Coal | RNA, RoW | hard coal mine operation and hard coal preparation hard coal Cutoff, U - RNA (ecoinvent v3.10) market for hard coal hard coal Cutoff, U - RoW (ecoinvent v3.10) |
| Iron ore | N/A | N/A |
| Limestone | N/A | N/A |
| Lime | RoW RNA | lime production, milled, loose lime Cutoff, U - RoW (ecoinvent v3.10) Quicklime, at plant (US LCI, matched to ecoinvent v3.10 upstreams) |
| Coke | RoW | coke production coke Cutoff, U - RoW (ecoinvent v3.10) |
| Sinter | N/A | N/A |
| Ferroalloys / other alloying elements | RoW, GLO | All from ecoinvent v3.10, unless indicated otherwise: aluminum, primary ingot, at plant, RNA (US LCI, matched to ecoinvent v3.10 upstreams) copper, anode to generic market for copper-rich materials copper-rich materials Cutoff, U - GLO ferrochromium production, high-carbon, 55% Cr ferrochromium, high-carbon, 55% Cr Cutoff, U - RoW ferromanganese production, high-coal, 74.5% Mn ferromanganese, high-coal, 74.5% Mn Cutoff, U - RoW ferroniobium production, from pyrochlore concentrate, 66% Nb ferroniobium, 66% Nb Cutoff, U - RoW ferrosilicon production ferrosilicon Cutoff, U - RoW molybdenum production molybdenum Cutoff, U - RoW molybdenum trioxide production molybdenum trioxide Cutoff, U - GLO silicon carbide production silicon carbide Cutoff, U - RoW smelting and refining of nickel concentrate, 16% Ni nickel, class 1 Cutoff, U - GLO titanium production titanium Cutoff, U - GLO |
| Zinc | N/A | N/A |
| Pig iron | RoW | pig iron production pig iron Cutoff, U - RoW (ecoinvent v3.10) |
| Sponge iron | Confidential primary data | Confidential primary data |
| Iron pellets | N/A | N/A |
| Semi-finished steel products: billets, slabs, blooms, beam blanks, rounds | USA | Primary data |
| Semi-finished steel products: billets, slabs, blooms, beam blanks, rounds | Not USA/Canada | N/A |
| Hot-rolled sections | USA | Primary data |



| Input / Unit Process | Origin of Material or Process | LCI data source reference |
|---|---|---|
| Grid electricity - delivered | USA - Subregion specific (SERC, RF, TERC) | eGRID 2022 subregion power type mixes. Mapped to ecoinvent v3.10 sub-region specific datasets: electricity production, deep geothermal electricity, high voltage Cutoff, U - US electricity production, hard coal electricity, high voltage Cutoff, U - US electricity production, hydro, run-of-river electricity, high voltage Cutoff, U - US electricity production, lignite electricity, high voltage Cutoff, U - US electricity production, natural gas, conventional power plant electricity, high voltage Cutoff, U - US electricity production, nuclear, boiling water reactor electricity, high voltage Cutoff, U - US electricity production, oil electricity, high voltage Cutoff, U - US electricity production, photovoltaic, 570kWp open ground installation, multi-Si electricity, low voltage Cutoff, U - US electricity production, wind, >3MW turbine, onshore electricity, high voltage Cutoff, U - US electricity production, wind, <1MW turbine, onshore electricity, high voltage Cutoff, U - US heat and power co-generation, biogas, gas engine electricity, high voltage Cutoff, U - US |
| Grid electricity - delivered | Canada | N/A |
| Grid electricity - delivered | Not USA/Canada | N/A |
| Grid electricity - Energy Attribute Certificates (EACs) (e.g. RECs, PPAs, GOs) | USA | electricity production, photovoltaic, 3kWp slanted-roof installation, single-Si, panel, mounted electricity, low voltage Cutoff, U - US-SERC (ecoinvent v3.10) |
| Transportation | USA (incl. to/from USA) | Transport, barge, average fuel mix (US LCI, mapped to ecoinvent v3.10: transport, freight, inland waterways, barge tanker transport, freight, inland waterways, barge tanker Cutoff, U - RoW) Transport, combination truck, short-haul, diesel powered- US (US LCI, mapped to ecoinvent v3.10: diesel production, petroleum refinery operation diesel Cutoff, U - RoW) Transport, combination truck, long-haul, diesel powered- US (US LCI, mapped to ecoinvent v3.10: diesel production, petroleum refinery operation diesel Cutoff, U - RoW) Transport, ocean freighter, average fuel mix (US LCI, mapped to ecoinvent v3.10: transport, freight, sea, container ship transport, freight, sea, container ship Cutoff, U - GLO) Transport, train, diesel powered (US LCI, mapped to ecoinvent v3.10: diesel production, petroleum refinery operation diesel Cutoff, U - RoW) |
| Transportation | Other | N/A |
| Fabrication (including fabrication scrap rate that determines the quantity of inputted unfabricated steel product in A1; transport to fabricator impacts (A2); and fabrication operations impacts (A3)) | Hot-rolled sections, plate, HSS | Primary data |
| Other (any input not listed above that contributes at least 10% to total A1:A3 result for any impact measure) | N/A | N/A |

Table 40: A1 background data - EAF (ecoinvent v3.10, cutoff unit process models)

| Material | Geographic Region | Dataset | Provider | Proxy* | Year Dataset Represents |
|------------------------|-------------------|--|------------------------------|--------|-------------------------|
| Pig Iron | RoW | pig iron production pig iron Cutoff, U - RoW | ecoinvent | No | 2023 |
| DRI | Confidential | primary data | | No | 2023 |
| Natural Gas Production | US | natural gas, high pressure, domestic supply with seasonal storage natural gas, high pressure Cutoff, U - US | ecoinvent | No | 2023 |
| Natural Gas Combustion | RoW | heat production, natural gas, at industrial furnace >100kW heat, district or industrial, natural gas Cutoff, U - RoW | ecoinvent | No | 2023 |
| Diesel | GLO | diesel, burned in building machine diesel, burned in building machine Cutoff, U - GLO | ecoinvent | No | 2023 |
| Gasoline | GLO | petrol, unleaded, burned in machinery petrol, unleaded, burned in machinery Cutoff, U - GLO | ecoinvent | No | 2023 |
| Propane | GLO | propane, burned in building machine propane, burned in building machine Cutoff, U - GLO | ecoinvent | No | 2023 |
| Acetylene | RoW | acetylene production acetylene Cutoff, U - RoW | ecoinvent | No | 2023 |
| Municipal Water | RoW | tap water production, conventional treatment tap water Cutoff, U - RoW | ecoinvent | No | 2023 |
| Ground Water | N/A | Elementary flow, resource, in ground, water, unspecified natural origin | ecoinvent | No | 2023 |
| Surface Water | N/A | Elementary flow, resource, in water, water (fresh water) | ecoinvent | No | 2023 |
| Silicomanganese | RoW | ferromanganese production, high-coal, 74.5% Mn ferromanganese, high-coal, 74.5% Mn Cutoff, U - RoW | ecoinvent | No | 2023 |
| Ferro Silicon | RoW | ferrosilicon production ferrosilicon Cutoff, U - RoW | ecoinvent | No | 2023 |
| Ferromanganese | RoW | ferromanganese production, high-coal, 74.5% Mn ferromanganese, high-coal, 74.5% Mn Cutoff, U - RoW | ecoinvent | No | 2023 |
| Iron Silicide | RoW | ferrosilicon production ferrosilicon Cutoff, U - RoW | ecoinvent | No | 2023 |
| Vanadium | GLO | titanium production titanium Cutoff, U - GLO | ecoinvent | No | 2023 |
| Ferro Chromium | RoW | ferrochromium production, high-carbon, 55% Cr ferrochromium, high-carbon, 55% Cr Cutoff, U - RoW | ecoinvent | No | 2023 |
| Nickel | GLO | smelting and refining of nickel concentrate, 16% Ni nickel, class 1 Cutoff, U - GLO | ecoinvent | No | 2023 |
| Calcium Silicate | RoW | silica sand production silica sand Cutoff, U - RoW | ecoinvent | No | 2023 |
| Ferriobium | RoW | ferriobium production, from pyrochlore concentrate, 66% Nb ferriobium, 66% Nb Cutoff, U - RoW | ecoinvent | No | 2023 |
| Chromium | RoW | ferrochromium production, high-carbon, 55% Cr ferrochromium, high-carbon, 55% Cr Cutoff, U - RoW | ecoinvent | No | 2023 |
| Aluminum | RNA | Aluminum, primary ingot, at plant, RNA | USLCI, matched to ecoinvent. | No | 2024, 2023 |
| Aluminum Oxide | RoW | market for aluminium oxide, metallurgical aluminium oxide, metallurgical Cutoff, U - RoW | ecoinvent | No | 2023 |
| Molybdenum Oxide | GLO | molybdenum trioxide production molybdenum trioxide Cutoff, U - GLO | ecoinvent | No | 2023 |
| Ferromolybdenum | RoW | molybdenum production molybdenum Cutoff, U - RoW | ecoinvent | No | 2023 |
| Vanadium Nitrate | GLO | titanium production titanium Cutoff, U - GLO | ecoinvent | No | 2023 |
| Copper | GLO | copper, anode to generic market for copper-rich materials copper-rich materials Cutoff, U - GLO | ecoinvent | No | 2023 |
| Sulfur | RoW | sulfur production, petroleum refinery operation sulfur Cutoff, U - RoW | ecoinvent | No | 2023 |
| Phosphorous | RoW | phosphorus production, white, liquid phosphorus, white, liquid Cutoff, U - RoW | ecoinvent | No | 2023 |
| Silicon Carbide | RoW | silicon carbide production silicon carbide Cutoff, U - RoW | ecoinvent | No | 2023 |

| Material | Geographic Region | Dataset | Provider | Proxy* | Year Dataset Represents |
|---------------------|-------------------|---|------------------------------|--------|-------------------------|
| Iron Phosphide | RoW RoW | iron ore beneficiation iron ore concentrate Cutoff, U - RoW phosphorous chloride production phosphorous chloride Cutoff, U - RoW | ecoinvent | No | 2023 |
| Ferrochrome | RoW | ferrochromium production, high-carbon, 55% Cr ferrochromium, high-carbon, 55% Cr Cutoff, U - RoW | ecoinvent | No | 2023 |
| Titanium | GLO | titanium production titanium Cutoff, U - GLO | ecoinvent | No | 2023 |
| Ferroboron | GLO | boron carbide production boron carbide Cutoff, U - GLO | ecoinvent | No | 2023 |
| Graphite | RoW | graphite production graphite Cutoff, U - RoW | ecoinvent | No | 2023 |
| Anthracite | RNA | hard coal mine operation and hard coal preparation hard coal Cutoff, U - RNA | ecoinvent | No | 2023 |
| Ladle Carbon | RoW | market for hard coal hard coal Cutoff, U - RoW | ecoinvent | No | 2023 |
| Ca Wire | RoW RoW | calcium carbonate production, precipitated calcium carbonate, precipitated Cutoff, U - RoW wire drawing, copper wire drawing, copper Cutoff, U - RoW | ecoinvent | No | 2023 |
| Al Wire | RoW RoW | aluminium production, primary, ingot aluminium, primary, ingot Cutoff, U - RoW wire drawing, steel wire drawing, steel Cutoff, U - RoW | ecoinvent | No | 2023 |
| CASi Wire | RoW RoW RoW | calcium carbonate production, precipitated calcium carbonate, precipitated Cutoff, U - RoW silicone product production silicone product Cutoff, U - RoW wire drawing, steel wire drawing, steel Cutoff, U - RoW | ecoinvent | No | 2023 |
| C wire | GLO RoW | carbon black production carbon black Cutoff, U - GLO wire drawing, steel wire drawing, steel Cutoff, U - RoW | ecoinvent | No | 2023 |
| Calcium Carbide | RoW | calcium carbide production, technical grade calcium carbide, technical grade Cutoff, U - RoW | ecoinvent | No | 2023 |
| CaSi Cored Wire | RoW RoW RoW | calcium carbonate production, precipitated calcium carbonate, precipitated Cutoff, U - RoW silicone product production silicone product Cutoff, U - RoW wire drawing, steel wire drawing, steel Cutoff, U - RoW | ecoinvent | No | 2023 |
| Charge Carbon | RoW | market for hard coal hard coal Cutoff, U - RoW | ecoinvent | No | 2023 |
| Coke | RoW | coke production coke Cutoff, U - RoW | ecoinvent | No | 2023 |
| Dolomite | RoW | dolomite production dolomite Cutoff, U - RoW | ecoinvent | No | 2023 |
| Graphite Electrodes | RoW | graphite production graphite Cutoff, U - RoW | ecoinvent | No | 2023 |
| Injection Carbon | RoW | market for hard coal hard coal Cutoff, U - RoW | ecoinvent | No | 2023 |
| Lime | RoW | lime production, milled, loose lime Cutoff, U - RoW | ecoinvent | No | 2023 |
| Quick Lime | RNA | Quicklime, at plant | USLCI, matched to ecoinvent. | No | 2024, 2023 |
| Oils | RoW | lubricating oil production lubricating oil Cutoff, U - RoW | ecoinvent | No | 2023 |
| Refractory | RoW | refractory production, basic, packed refractory, basic, packed Cutoff, U - RoW | ecoinvent | No | 2023 |
| Sand | N/A | Elementary flow, resource, in ground, sand, quartz | ecoinvent | No | 2023 |
| Oxygen Gas | RoW | industrial gases production, cryogenic air separation oxygen, liquid Cutoff, U - RoW | ecoinvent | No | 2023 |
| Nitrogen Gas | RoW | industrial gases production, cryogenic air separation nitrogen, liquid Cutoff, U - RoW | ecoinvent | No | 2023 |
| Argon Gas | RoW | industrial gases production, cryogenic air separation argon, crude, liquid Cutoff, U - RoW | ecoinvent | No | 2023 |



| Material | Geographic Region | Dataset | Provider | Proxy* | Year Dataset Represents |
|-------------------------|-------------------------|---|------------------------------|--------|-------------------------|
| Calcium | RoW | calcium carbide production, technical grade calcium carbide, technical grade Cutoff, U - RoW | ecoinvent | No | 2023 |
| Samplers | RoW | cast iron production cast iron Cutoff, U - RoW | ecoinvent | No | 2023 |
| Purchased Electricity | US – subregion specific | electricity production, wind, >3MW turbine, onshore electricity, high voltage Cutoff, U - US electricity production, hard coal electricity, high voltage Cutoff, U - US heat and power co-generation, biogas, gas engine electricity, high voltage Cutoff, U - US electricity production, deep geothermal electricity, high voltage Cutoff, U - US electricity production, natural gas, conventional power plant electricity, high voltage Cutoff, U - US electricity production, oil electricity, high voltage Cutoff, U - US electricity production, nuclear, boiling water reactor electricity, high voltage Cutoff, U - US electricity production, hydro, run-of-river electricity, high voltage Cutoff, U - US electricity production, lignite electricity, high voltage Cutoff, U - US electricity production, wind, <1MW turbine, onshore electricity, high voltage Cutoff, U - US electricity production, photovoltaic, 570kWp open ground installation, multi-Si electricity, low voltage Cutoff, U - US | ecoinvent | No | 2023 |
| PPA – Solar | US-SERC | electricity production, photovoltaic, 3kWp slanted-roof installation, single-Si, panel, mounted electricity, low voltage Cutoff, U - US-SERC | ecoinvent | No | 2023 |
| REC- Wind/Solar | US-RFC | electricity production, wind, >3MW turbine, onshore electricity, high voltage Cutoff, U - US-RFC electricity production, photovoltaic, 570kWp open ground installation, multi-Si electricity, low voltage Cutoff, U - US-RFC | ecoinvent | No | 2023 |
| Inbound Ship | GLO | Transport, ocean freighter, average fuel mix | USLCI, matched to ecoinvent. | No | 2024, 2023 |
| Inbound Barge | US | Transport, barge, average fuel mix | USLCI, matched to ecoinvent. | No | 2024, 2023 |
| Inbound Truck | RNA | Transport, combination truck, short-haul, diesel powered-US Transport, combination truck, long-haul, diesel powered-US | USLCI, matched to ecoinvent. | No | 2024, 2023 |
| Inbound Rail | US | Transport, train, diesel powered | USLCI, matched to ecoinvent. | No | 2024, 2023 |
| Wastewater to POTW | RoW | treatment of wastewater, average, wastewater treatment wastewater, average Cutoff, U - RoW | ecoinvent | No | 2023 |
| Mercury to Air | N/A | Elementary flow, emission to air, unspecified, mercury compounds | ecoinvent | No | 2023 |
| Nitrogen Dioxide to Air | | Elementary flow, emission to air, unspecified, nitrogen dioxide | ecoinvent | No | 2023 |
| Lead to Air | N/A | Elementary flow, emission to air, unspecified, lead II | ecoinvent | No | 2023 |



| Material | Geographic Region | Dataset | Provider | Proxy* | Year Dataset Represents |
|---------------------------|-------------------|--|-----------|--------|-------------------------|
| Arsenic to Air | N/A | Elementary flow, emission to air, unspecified, arsenic | ecoinvent | No | 2023 |
| Cadmium to Air | N/A | Elementary flow, emission to air, unspecified, cadmium compounds | ecoinvent | No | 2023 |
| Chromium to Air | N/A | Elementary flow, emission to air, unspecified, chromium compounds | ecoinvent | No | 2023 |
| Manganese to Air | N/A | Elementary flow, emission to air, unspecified, manganese II | ecoinvent | No | 2023 |
| Nickel to Air | N/A | Elementary flow, emission to air, unspecified, nickel compounds | ecoinvent | No | 2023 |
| Suspended Solids to Water | N/A | Elementary flow, emission to water, unspecified, suspended solids, unspecified | ecoinvent | No | 2023 |
| Iron to Water | N/A | Elementary flow, emission to water, unspecified, iron ion | ecoinvent | No | 2023 |
| Fluorine to Air | N/A | Elementary flow, emission to air, unspecified, fluorine | ecoinvent | No | 2023 |
| Beryllium to Air | N/A | Elementary flow, emission to air, unspecified, beryllium compounds | ecoinvent | No | 2023 |
| Aluminum Oxide to Air | RoW | market for aluminium oxide, metallurgical aluminium oxide, metallurgical Cutoff, U - RoW | ecoinvent | No | 2023 |
| Calcium Oxide to Air | N/A | Elementary flow, emission to air, unspecified, calcium II | ecoinvent | No | 2023 |
| Copper Oxide to Air | N/A | Elementary flow, emission to air, unspecified, copper oxide | ecoinvent | No | 2023 |
| Iron Oxide to Air | N/A | Elementary flow, emission to air, unspecified, iron II | ecoinvent | No | 2023 |
| Lead Oxide to Air | N/A | Elementary flow, emission to air, unspecified, lead compounds | ecoinvent | No | 2023 |
| Magnesium Oxide to Air | N/A | Elementary flow, emission to air, unspecified, magnesium | ecoinvent | No | 2023 |
| Manganese Oxide to Air | N/A | Elementary flow, emission to air, unspecified, manganese II | ecoinvent | No | 2023 |
| Zinc Oxide to Air | N/A | Elementary flow, emission to air, unspecified, zinc oxide | ecoinvent | No | 2023 |
| Antimony to Air | N/A | Elementary flow, emission to air, unspecified, antimony oxide | ecoinvent | No | 2023 |
| Barium to Water | N/A | Elementary flow, emission to water, unspecified, barium compounds | ecoinvent | No | 2023 |
| Chromium to Water | N/A | Elementary flow, emission to water, unspecified, chromium compounds | ecoinvent | No | 2023 |
| Water to Water | N/A | Elementary flow, emission to water, lake, water, US | ecoinvent | No | 2023 |
| PAH to Air | N/A | Elementary flow, emission to air, unspecified, PAH, polycyclic aromatic hydrocarbons | ecoinvent | No | 2023 |
| Methane to Air | N/A | Elementary flow, emission to air, unspecified, methane | ecoinvent | No | 2023 |
| Water to Air | N/A | Elementary flow, emission to air, unspecified, water | ecoinvent | No | 2023 |
| Carbon Monoxide to Air | N/A | Elementary flow, emission to air, unspecified, carbon monoxide | ecoinvent | No | 2023 |
| HAPs to Air | N/A | Elementary flow, emission to air, unspecified, mercury compounds | ecoinvent | No | 2023 |
| Nitrous Oxide to Air | N/A | Elementary flow, emission to air, unspecified, nitrogen oxides | ecoinvent | No | 2023 |
| PM10 to Air | N/A | Elementary flow, emission to air, unspecified, particulate matter, >2.5um and <10um | ecoinvent | No | 2023 |
| PM2.5 to Air | N/A | Elementary flow, emission to air, unspecified, particulate matter, <2.5um | ecoinvent | No | 2023 |
| Sulfur Dioxide to Air | N/A | Elementary flow, emission to air, unspecified, sulfur dioxide | ecoinvent | No | 2023 |
| VOCs to Air | N/A | Elementary flow, emission to air, unspecified, VOC, volatile organic compounds | ecoinvent | No | 2023 |
| CO ₂ to Air | N/A | Elementary flow, emission to air, unspecified, carbon dioxide, fossil | ecoinvent | No | 2023 |



| Material | Geographic Region | Dataset | Provider | Proxy* | Year Dataset Represents |
|------------------------------------|-------------------|--|------------------------------|--------|-------------------------|
| Non Haz Landfill | RoW | treatment of inert waste, sanitary landfill inert waste Cutoff, U - RoW | ecoinvent | No | 2023 |
| Haz Waste Incineration | RoW | treatment of municipal solid waste, municipal incineration municipal solid waste Cutoff, U - RoW | ecoinvent | No | 2023 |
| General Trash | RoW | treatment of inert waste, sanitary landfill inert waste Cutoff, U - RoW | ecoinvent | No | 2023 |
| Sludge Solidification | RoW | treatment of sludge from steel rolling, residual material landfill sludge from steel rolling Cutoff, U - RoW | ecoinvent | No | 2023 |
| Shredder Fluff Landfill | RoW | treatment of inert waste, sanitary landfill inert waste Cutoff, U - RoW | ecoinvent | No | 2023 |
| Haz Waste Landfill | RoW | treatment of hazardous waste, underground deposit hazardous waste, for underground deposit Cutoff, U - RoW | ecoinvent | No | 2023 |
| Outbound Truck | RNA | Transport, combination truck, diesel powered | USLCI, matched to ecoinvent. | No | 2024, 2023 |
| Outbound Rail | US | Transport, train, diesel powered | USLCI, matched to ecoinvent. | No | 2024, 2023 |
| Steel Scrap sorting and processing | US | sorting and pressing of iron scrap iron scrap, sorted, pressed Cutoff, U - RoW | ecoinvent | Yes | 2023 |

* Geo. = Geographical proxy, Tech. = Technological proxy

Table 41: A1 background data – Section Rolling (ecoinvent v3.10, cutoff unit process models)

| Material | Geographic Region | Dataset | Provider | Proxy* | Year Dataset Represents |
|-----------------------|-------------------------|--|-----------|--------|-------------------------|
| Oil | RoW | lubricating oil production lubricating oil Cutoff, U - RoW | ecoinvent | No | 2023 |
| Refractory | RoW | refractory production, basic, packed refractory, basic, packed Cutoff, U - RoW | ecoinvent | No | 2023 |
| Purchased Electricity | US – subregion specific | electricity production, wind, >3MW turbine, onshore electricity, high voltage Cutoff, U - US electricity production, hard coal electricity, high voltage Cutoff, U - US heat and power co-generation, biogas, gas engine electricity, high voltage Cutoff, U - US electricity production, deep geothermal electricity, high voltage Cutoff, U - US electricity production, natural gas, conventional power plant electricity, high voltage Cutoff, U - US electricity production, oil electricity, high voltage Cutoff, U - US electricity production, nuclear, boiling water reactor electricity, high voltage Cutoff, U - US electricity production, hydro, run-of-river electricity, high voltage Cutoff, U - US electricity production, lignite electricity, high voltage Cutoff, U - US electricity production, wind, <1MW turbine, onshore electricity, high voltage Cutoff, U - US | ecoinvent | No | 2023 |



| Material | Geographic Region | Dataset | Provider | Proxy* | Year Dataset Represents |
|---------------------------|-------------------|--|------------------------------|--------|-------------------------|
| | | electricity production, photovoltaic, 570kWp open ground installation, multi-Si electricity, low voltage Cutoff, U - US | | | |
| PPA – Solar | US-SERC | electricity production, photovoltaic, 3kWp slanted-roof installation, single-Si, panel, mounted electricity, low voltage Cutoff, U - US-SERC | ecoinvent | No | 2023 |
| Natural Gas Production | US | natural gas, high pressure, domestic supply with seasonal storage natural gas, high pressure Cutoff, U - US | ecoinvent | No | 2023 |
| Natural Gas Combustion | RoW | heat production, natural gas, at industrial furnace >100kW heat, district or industrial, natural gas Cutoff, U - RoW | ecoinvent | No | 2023 |
| Gasoline | GLO | petrol, unleaded, burned in machinery petrol, unleaded, burned in machinery Cutoff, U - GLO | ecoinvent | No | 2023 |
| Propane | GLO | propane, burned in building machine propane, burned in building machine Cutoff, U - GLO | ecoinvent | No | 2023 |
| Diesel | GLO | diesel, burned in building machine diesel, burned in building machine Cutoff, U - GLO | ecoinvent | No | 2023 |
| Municipal Water | RoW | tap water production, conventional treatment tap water Cutoff, U - RoW | ecoinvent | No | 2023 |
| Ground Water | N/A | Elementary flow, resource, in ground, water, unspecified natural origin | ecoinvent | No | 2023 |
| Surface Water | N/A | Elementary flow, resource, in water, water (fresh water) | ecoinvent | No | 2023 |
| Dunnage Packaging | RoW | beam, hardwood, raw, kiln drying to u=20% sawnwood, beam, hardwood, raw, dried (u=20%) Cutoff, U - RoW | ecoinvent | No | 2023 |
| Steel Banding | RoW | steel production, chromium steel 18/8, hot rolled steel, chromium steel 18/8, hot rolled Cutoff, U - RoW | ecoinvent | No | 2023 |
| VCI Bag | RoW | packaging film production, low density polyethylene packaging film, low density polyethylene Cutoff, U - RoW | ecoinvent | No | 2023 |
| Inbound Rail | US | Transport, train, diesel powered | USLCI, matched to ecoinvent. | No | 2023, 2024 |
| Inbound Truck | RNA | Transport, combination truck, diesel powered | USLCI, matched to ecoinvent. | No | 2023, 2024 |
| Methane to Air | N/A | Elementary flow, emission to air, unspecified, methane | ecoinvent | No | 2023 |
| Wastewater to POTW | RoW | treatment of wastewater, average, wastewater treatment wastewater, average Cutoff, U - RoW | ecoinvent | No | 2023 |
| CO ₂ to Air | N/A | Elementary flow, emission to air, unspecified, carbon dioxide, fossil | ecoinvent | No | 2023 |
| Nitrous Oxide to Air | N/A | Elementary flow, emission to air, unspecified, nitrogen oxides | ecoinvent | No | 2023 |
| Carbon Monoxide to Air | N/A | Elementary flow, emission to air, unspecified, carbon monoxide | ecoinvent | No | 2023 |
| PM10 to Air | N/A | Elementary flow, emission to air, unspecified, particulate matter, >2.5um and <10um | ecoinvent | No | 2023 |
| PM2.5 to Air | N/A | Elementary flow, emission to air, unspecified, particulate matter, <2.5um | ecoinvent | No | 2023 |
| Sulfur Dioxide to Air | N/A | Elementary flow, emission to air, unspecified, sulfur dioxide | ecoinvent | No | 2023 |
| VOC to Air | N/A | Elementary flow, emission to air, unspecified, VOC, volatile organic compounds | ecoinvent | No | 2023 |
| Suspended Solids to Water | N/A | Elementary flow, emission to water, unspecified, suspended solids, unspecified | ecoinvent | No | 2023 |

| Material | Geographic Region | Dataset | Provider | Proxy* | Year Dataset Represents |
|-----------------------------|-------------------|--|-----------|--------|-------------------------|
| Iron to Water | N/A | Elementary flow, emission to water, unspecified, iron ion | ecoinvent | No | 2023 |
| Lead Oxide to Air | N/A | Elementary flow, emission to air, unspecified, lead compounds | ecoinvent | No | 2023 |
| Barium to Water | N/A | Elementary flow, emission to water, unspecified, barium compounds | ecoinvent | No | 2023 |
| Chromium to Water | N/A | Elementary flow, emission to water, unspecified, chromium compounds | ecoinvent | No | 2023 |
| Copper to Water | N/A | Elementary flow, emission to water, unspecified, copper compounds | ecoinvent | No | 2023 |
| Lead to Water | N/A | Elementary flow, emission to water, unspecified, lead compounds | ecoinvent | No | 2023 |
| Manganese to Water | N/A | Elementary flow, emission to water, unspecified, manganese | ecoinvent | No | 2023 |
| Nickel to Water | N/A | Elementary flow, emission to water, unspecified, nickel compounds | ecoinvent | No | 2023 |
| Zinc to Water | N/A | Elementary flow, emission to water, unspecified, zinc compounds | ecoinvent | No | 2023 |
| Water to Water | N/A | Elementary flow, emission to water, lake, water, US | ecoinvent | No | 2023 |
| Lithium Carbonate to Water | N/A | Elementary flow, emission to water, unspecified, lithium carbonate | ecoinvent | No | 2023 |
| Water to Air | N/A | Elementary flow, emission to air, unspecified, water | ecoinvent | No | 2023 |
| 2-Methylnaphthalene to Air | N/A | Elementary flow, emission to air, unspecified, methyl naphthalenes | ecoinvent | No | 2023 |
| Ammonia to Air | N/A | Elementary flow, emission to air, unspecified, ammonia | ecoinvent | No | 2023 |
| Ethane to Air | N/A | Elementary flow, emission to air, unspecified, ethane | ecoinvent | No | 2023 |
| Fluorides to Air | N/A | Elementary flow, emission to air, unspecified, fluoride | ecoinvent | No | 2023 |
| Sulfuric Acid to Air | N/A | Elementary flow, emission to air, unspecified, sulfuric acid | ecoinvent | No | 2023 |
| 1,3-Butadiene to Air | N/A | Elementary flow, emission to air, unspecified, 2,3-Dimethyl-1,3-butadiene | ecoinvent | No | 2023 |
| 1,4-Dichlorobenzene to Air | N/A | Elementary flow, emission to air, unspecified, 1,4-dichlorobenzene | ecoinvent | No | 2023 |
| Acetaldehyde to Air | N/A | Elementary flow, emission to air, unspecified, acetaldehyde | ecoinvent | No | 2023 |
| Acrolein to Air | N/A | Elementary flow, emission to air, unspecified, acrolein | ecoinvent | No | 2023 |
| Benzene to Air | N/A | Elementary flow, emission to air, unspecified, benzene | ecoinvent | No | 2023 |
| Carbon Disulfide to Air | N/A | Elementary flow, emission to air, unspecified, carbon disulfide | ecoinvent | No | 2023 |
| Carbon Tetrachloride to Air | N/A | Elementary flow, emission to air, low population density, carbon tetrachloride | ecoinvent | No | 2023 |
| Chlorine to Air | N/A | Elementary flow, emission to air, unspecified, chlorine | ecoinvent | No | 2023 |
| Chloroform to Air | N/A | Elementary flow, emission to air, unspecified, chloroform | ecoinvent | No | 2023 |
| Ethyl Benzene to Air | N/A | Elementary flow, emission to air, unspecified, ethyl benzene | ecoinvent | No | 2023 |
| Formaldehyde to Air | N/A | Elementary flow, emission to air, unspecified, formaldehyde | ecoinvent | No | 2023 |
| Hydrochloric Acid to Air | N/A | Elementary flow, emission to air, unspecified, hydrochloric acid | ecoinvent | No | 2023 |
| Hydrogen Fluoride to Air | N/A | Elementary flow, emission to air, unspecified, hydrogen fluoride | ecoinvent | No | 2023 |
| Methanol to Air | N/A | Elementary flow, emission to air, unspecified, methanol | ecoinvent | No | 2023 |



| Material | Geographic Region | Dataset | Provider | Proxy* | Year Dataset Represents |
|-------------------------------|-------------------|--|-----------------------------|--------|-------------------------|
| Methyl Chloride to Air | N/A | Elementary flow, emission to air, unspecified, chloromethane | ecoinvent | No | 2023 |
| Methyl Ethyl Ketone to Air | N/A | Elementary flow, emission to air, unspecified, methyl ethyl ketone | ecoinvent | No | 2023 |
| Methyl Isobutyl Ketone to Air | N/A | Elementary flow, emission to air, unspecified, methyl-isopropylketone | ecoinvent | No | 2023 |
| Naphthalene to Air | N/A | Elementary flow, emission to air, unspecified, naphthalene | ecoinvent | No | 2023 |
| PAH to Air | N/A | Elementary flow, emission to air, unspecified, PAH, polycyclic aromatic hydrocarbons | ecoinvent | No | 2023 |
| Styrene to Air | N/A | Elementary flow, emission to air, unspecified, styrene | ecoinvent | No | 2023 |
| Toluene to Air | N/A | Elementary flow, emission to air, unspecified, toluene | ecoinvent | No | 2023 |
| Trichloroethylene to Air | N/A | Elementary flow, emission to air, unspecified, trichloroethylene | ecoinvent | No | 2023 |
| Non Haz Waste Landfill | RoW | treatment of inert waste, sanitary landfill inert waste Cutoff, U - RoW | ecoinvent | No | 2023 |
| Haz Waste Incineration | RoW | treatment of municipal solid waste, municipal incineration municipal solid waste Cutoff, U - RoW | ecoinvent | No | 2023 |
| General Trash | RoW | treatment of inert waste, sanitary landfill inert waste Cutoff, U - RoW | ecoinvent | No | 2023 |
| Sludge Solidification | RoW | treatment of sludge from steel rolling, residual material landfill sludge from steel rolling Cutoff, U - RoW | ecoinvent | No | 2023 |
| Haz Waste Landfill | RoW | treatment of hazardous waste, underground deposit hazardous waste, for underground deposit Cutoff, U - RoW | ecoinvent | No | 2023 |
| Outbound Truck | RNA | Transport, combination truck, diesel powered | USLCI, matched to ecoinvent | RNA | 2023, 2024 |

* Geo. = Geographical proxy, Tech. = Technological proxy

Table 42: A2 background data (ecoinvent v3.10, cutoff unit process models)

| Material | Geographic region | Dataset | Provider | Proxy?* |
|-----------------|-------------------|--|-----------------------------|---------|
| Truck transport | RNA | Transport, combination truck, diesel powered | USLCI, matched to ecoinvent | No |
| Rail transport | US | Transport, train, diesel powered | USLCI, matched to ecoinvent | No |

*Geo. – Geographical proxy, Tech. = Technical proxy

Table 43: A3 background data (ecoinvent v3.10, cutoff unit process models)

| Material | Geographic region | Dataset | Provider | Proxy?* | Year Dataset Represents |
|--------------------------|---------------------------------|---|---|---------|-------------------------|
| Fluids & oil | RoW | lubricating oil production lubricating oil Cutoff, U | ecoinvent | No | 2023 |
| Stick welding electrodes | GLO RoW RoW RoW GLO | Steel cold rolled coil calcium carbonate production, precipitated calcium carbonate, precipitated Cutoff, U titanium dioxide production, sulfate process titanium dioxide Cutoff, U | The World Steel Association (CRC) ecoinvent (all others) | Tech | 2022 |

| Material | Geographic region | Dataset | Provider | Proxy?* | Year Dataset Represents |
|--------------------------|---|---|--|---------|-------------------------|
| | RoW RoW RoW RoW RoW | ferromanganese production, high-coal, 74.5% Mn ferromanganese, high-coal, 74.5% Mn Cutoff, U market for zircon zircon Cutoff, U cellulose fibre production cellulose fibre Cutoff, U silica sand production silica sand Cutoff, U sodium silicate production, furnace process, solid product sodium silicate, solid Cutoff, U kaolin production kaolin Cutoff, U titanium dioxide production, sulfate process titanium dioxide Cutoff, U zirconium oxide production zirconium oxide Cutoff, U | | | |
| Flux core electrodes | GLO RoW RoW RoW RoW RNA RoW | Steel cold rolled coil calcium carbonate production, precipitated calcium carbonate, precipitated Cutoff, U titanium dioxide production, sulfate process titanium dioxide Cutoff, U ferromanganese production, high-coal, 74.5% Mn ferromanganese, high-coal, 74.5% Mn Cutoff, U silicon production, metallurgical grade silicon, metallurgical grade Cutoff, U sodium silicate production, furnace process, solid product sodium silicate, solid Cutoff, U Aluminum – primary extruded aluminum titanium dioxide production, sulfate process titanium dioxide Cutoff, U | The World Steel Association (CRC) The Aluminum Association (Aluminum) ecoinvent (all others) | Tech | 2022 |
| Submerged arc electrodes | GLO RoW UN-Oceania RoW RoW RoW | Steel wire rod silica sand production silica sand Cutoff, U aluminium oxide production aluminium oxide, non-metallurgical Cutoff, U Barium Fluoride (chlor-alkali electrolysis, membrane cell sodium hydroxide, without water, in 50% solution state Cutoff, U & water production, deionised water, deionised Cutoff, U) ferromanganese production, high-coal, 74.5% Mn ferromanganese, high-coal, 74.5% Mn Cutoff, U magnesium production, electrolysis magnesium Cutoff, U | The World Steel Association (Steel wire rod) ecoinvent (all others) | Tech | 2022 |
| Metal core electrodes | GLO RoW RoW | Steel cold rolled coil calcium carbonate production, precipitated calcium carbonate, precipitated Cutoff, U ferromanganese production, high-coal, 74.5% Mn ferromanganese, high-coal, 74.5% Mn Cutoff, U | The World Steel Association (CRC) ecoinvent (all others) | Tech | 2022 |
| Gas metal Arc Electrodes | GLO RoW | Steel cold rolled coil ferromanganese production, high-coal, 74.5% Mn ferromanganese, high-coal, 74.5% Mn Cutoff, U | The World Steel Association (CRC) ecoinvent | Tech | 2022 |
| Steel wire | GLO | Steel wire rod | The World Steel Association | No | 2022 |



| Material | Geographic region | Dataset | Provider | Proxy?* | Year Dataset Represents |
|----------------------------|---|---|---|---------|-------------------------|
| Welding flux | RNA RoW RoW GLO GLO RoW RoW RoW RoW | Aluminum – primary extruded aluminum Barium Fluoride (chlor-alkali electrolysis, membrane cell sodium hydroxide, without water, in 50% solution state Cutoff, U & water production, deionised water, deionised Cutoff, U) fluorspar production, 97% purity fluorspar, 97% purity Cutoff, U Steel wire rod magnesium production, electrolysis magnesium Cutoff, U ferromanganese production, high-coal, 74.5% Mn ferromanganese, high-coal, 74.5% Mn Cutoff, U silica sand production silica sand Cutoff, U titanium dioxide production, sulfate process titanium dioxide Cutoff, U | The Aluminum Association (Aluminum) The World Steel Association (steel wire rod) ecoinvent (all others) | Tech | 2022 |
| Acetylene, compressed | RoW | acetylene production acetylene Cutoff, U | ecoinvent | No | 2023 |
| Argon, compressed | RoW | industrial gases production, cryogenic air separation argon, crude, liquid Cutoff, U | ecoinvent | No | 2023 |
| Argon, liquid | RoW | argon production, liquid argon, liquid Cutoff, U | ecoinvent | No | 2023 |
| Carbon dioxide, compressed | RoW | carbon dioxide production, liquid carbon dioxide, liquid Cutoff, S | ecoinvent | No | 2023 |
| Carbon dioxide, liquid | RoW | carbon dioxide production, liquid carbon dioxide, liquid Cutoff, S | ecoinvent | No | 2023 |
| Helium, compressed | GLO | natural gas liquids production helium, crude Cutoff, U | ecoinvent | No | 2023 |
| Natural gas, compressed | GLO | natural gas liquids production natural gas liquids Cutoff, U | ecoinvent | No | 2023 |
| Nitrogen, compressed | RoW | industrial gases production, cryogenic air separation nitrogen, liquid Cutoff, U | ecoinvent | No | 2023 |
| Nitrogen, liquid | RoW | industrial gases production, cryogenic air separation nitrogen, liquid Cutoff, U | ecoinvent | No | 2023 |
| Oxygen, compressed | RoW | industrial gases production, cryogenic air separation oxygen, liquid Cutoff, U | ecoinvent | No | 2023 |
| Oxygen, liquid | RoW | industrial gases production, cryogenic air separation oxygen, liquid Cutoff, U | ecoinvent | No | 2023 |
| Propane, compressed | GLO | natural gas liquids fractionation propane Cutoff, U | ecoinvent | No | 2023 |
| Propane, liquid | GLO | natural gas liquids fractionation propane Cutoff, U | ecoinvent | No | 2023 |
| Propylene, compressed | US | propylene production, from propane dehydrogenation propylene Cutoff, U | ecoinvent | No | 2023 |
| Propylene, liquid | US | propylene production, from propane dehydrogenation propylene Cutoff, U | ecoinvent | No | 2023 |
| Electricity | US – SERC US – WECC US – NPCC US – RFC US – HICC US – MRO US – PR US – TRE | market for electricity, medium voltage electricity, medium voltage Cutoff, U | ecoinvent | No | 2023 |



| Material | Geographic region | Dataset | Provider | Proxy?* | Year Dataset Represents |
|---------------------------------|-------------------|--|-----------------------------|---------|-------------------------|
| Propane, internal transport | GLO | natural gas liquids fractionation propane Cutoff, U | ecoinvent | No | 2023 |
| Gasoline, internal transport | GLO | petrol, unleaded, burned in machinery petrol, unleaded, burned in machinery Cutoff, U | ecoinvent | No | 2023 |
| Diesel, internal transport | RoW | diesel production, petroleum refinery operation diesel Cutoff, U | ecoinvent | No | 2023 |
| Kerosene, internal transport | RoW | kerosene production, petroleum refinery operation kerosene Cutoff, U | ecoinvent | No | 2023 |
| Thermal energy from natural gas | RoW | heat production, natural gas, at industrial furnace >100kW heat, district or industrial, natural gas Cutoff, U | ecoinvent | No | 2023 |
| Inbound truck transport | RNA | Transport, combination truck, diesel powered | USLCI, matched to ecoinvent | No | 2023, 2024 |
| Shop waste | GLO | treatment of waste glass, sanitary landfill waste glass Cutoff, U | ecoinvent | No | 2023 |
| Used oil | RoW | treatment of waste mineral oil, hazardous waste incineration waste mineral oil Cutoff, U | ecoinvent | No | 2023 |
| Argon emissions to air | N/A | Elementary flow, emission to air, unspecified, argon | ecoinvent | No | 2023 |
| Carbon dioxide emissions to air | N/A | Elementary flow, emission to air, unspecified, carbon dioxide, fossil | ecoinvent | No | 2023 |
| Helium emissions to air | N/A | Elementary flow, emission to air, unspecified, helium | ecoinvent | No | 2023 |
| Nitrogen emissions to air | N/A | Elementary flow, emission to air, unspecified, nitrogen | ecoinvent | No | 2023 |
| Oxygen emissions to air | N/A | Elementary flow, emission to air, unspecified, oxygen | ecoinvent | No | 2023 |
| Water emissions to air | N/A | Elementary flow, emission to air, unspecified, water | ecoinvent | No | 2023 |

Table 44: Modules C1-C4 background data (ecoinvent v3.10, cutoff unit process models)

| Material | Geographic region | Dataset | Provider | Proxy?* | Year Dataset Represents |
|-------------------------|-------------------|--|-----------|---------|-------------------------|
| Diesel, demolition | GLO | market for diesel, burned in building machine diesel, burned in building machine Cutoff, U - GLO | ecoinvent | No | 2023 |
| Electricity, demolition | US | market group for electricity, medium voltage electricity, medium voltage Cutoff, U - US | ecoinvent | No | 2023 |
| Landfill, steel scrap | RoW | treatment of scrap steel, inert material landfill scrap steel Cutoff, U - RoW | ecoinvent | No | 2023 |

Annex C: Renewable Energy Credits

Table 45: Renewable Electricity Details

| Parameter | Unit | Value |
|---|----------------|--|
| Renewable generator project name: | | Electric Reliability Council of Texas (ERCOT) |
| Tracking system ID (unique generator ID): | | [1] 91226-93324, 78479-87566 [2] 8393-28392 [3] 1-3295 [4] 17829-74337 [5] 35731-40730 [6] 32156-36812 [7] 36813-41812 [8] 1-23472 [9] 42677-58349 |
| Renewable facility/generator owner: | | [1] Briscoe Wind Farm, LLC [2] BNB Lamesa Solar, LLC [3] Javelina Wind Energy II - A [4] Javelina Wind Energy II - B [5] SE Juno 2, LLC [6] Elara Energy Project LLC [7] Elara Energy Project LLC [8] Sun Valley Solar Project LLC Unit 1 [9] Pattern Panhandle Wind 2 LLC |
| Renewable facility/generator location: | State/province | [1] Briscoe, TX [2] Lamesa, TX [3] Webb County, TX [4] Webb County, TX [5] Borden County, TX [6] Frio County, TX [7] Frio County, TX [8] Hill County, TX [9] Carson County, TX |
| Project vintage (build date): | Year | [1] [2] [3] 2015 [4] 2015 [5] [6] [7] [8] [9] |



| | | |
|--|--------------|---|
| Project generation date (year first produced renewable energy): | Year | [1] 2015 [2] 2017 [3] 2018 [4] 2018 [5] 2021 [6] 2021 [7] 2021 [8] 2022 [9] 2014 |
| Nameplate capacity of project: | MW | [1] 150 [2] 102 [3] 748.7 [4] 748.7 [5] 203.5 [6] 132.4 [7] 132.4 [8] 250 [9] 182 |
| Certificate type: | | Green-E |
| Certificate unique ID: | | N/A* |
| Month and year of renewable energy generation: | Month / year | N/A |
| Month and year certificate issued: | Month / year | N/A |
| Utility to which the project is interconnected: | | N/A |

* Not available



Annex D: Critical Review



VERIFICATION REPORT: AISC Hot-rolled structural steel sections

October 15, 2025

Rifat A. Karim
3872 Northaven Trl.
New Braunfels, TX 78132

Verification Report: AISC Hot-rolled structural steel sections LCA and EPDs

The program operator, Smart EPD, commissioned Rifat A. Karim to perform an external independent verification of the **Life Cycle Assessment of Hot-rolled structural steel sections**. **Rifat A. Karim** completed the review of the Life Cycle Assessment (LCA) study and respective Environment Product Declarations (EPD) on behalf of the commissioning organization, **American Institute of Steel Construction (AISC)**.

The review of the study was performed to demonstrate conformance with the following standards, general program instructions, and product category rules:

- International Organization for Standardization. (2000). *Environmental labels and declarations -- General principles* (ISO 14020:2000).
- International Organization for Standardization. (2006). *Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures* (ISO 14025:2006).
- International Organization for Standardization. (2020). *Environmental management - Life cycle assessment - Principles and framework* (ISO 14040:2006/Amd 1:2020).
- International Organization for Standardization. (2020). *Environmental management - Life cycle assessment -- Requirements and guidelines* (ISO 14044:2006/Amd 2:2020).
- International Organization for Standardization. (2014). *Environmental management -- Life cycle assessment -- Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006*. (ISO/TS 14071:2014).
- Smart EPD (2022). *General Program Instructions for Smart EPD*. Version 1.0, November 2022.
- Smart EPD PCR Part A: Product Category Rules for Building and Construction Products and Services (v1.2, 2025)
- Smart EPD PCR Part B: Designated Steel Construction Products (v3.0, 2025).

The independent third-party verification was conducted by an external expert per ISO 14044:2006 Section 6.2: Critical review by internal or external expert:

Reviewer Name : Rifat A. Karim

Reviewer Title : President

Reviewer Organization : ARII Environmental Services LLC.



VERIFICATION REPORT: AISC Hot-rolled structural steel sections

REVIEW SCOPE

The intent of this review was to provide an external independent third-party critical review of a completed LCA study project report and verification of two (2) respective EPDs. The EPDs generated from this LCA study include the following:

- Hot-rolled structural steel sections
- Fabrication process for structural steel

REVIEW PROCESS

The LCA review and EPD verification involved assessing conformance to the requirements set forth by the applicable ISO standards, SmartEPD Part A & Part B PCRs & ISO 21930:2014 and the most recent version of Smart EPD's General Program Instructions (GPIs). The LCA project report review and EPD verification process report were conducted utilizing the Smart EPD project portal.

The LCA study report and EPDs were reviewed and deemed by this **independent** and **external** reviewer to conform to the applicable ISO standards, PCRs, and General Program Instructions.

VERIFICATION STATEMENT

Based on the independent verification objectives, the **Life Cycle Assessment of Hot-rolled structural steel sections on October 2025 was** prepared for **AISC**, and the respective two (2) EPDs mentioned above (in the review scope section): by **John Beath Environmental LLC**, were reviewed and verified to be **in conformance** with the applicable ISO standards referenced above, the SmartEPD Part A & Part B PCRs and Smart EPD's General Program Instructions. The plausibility, quality, and accuracy of the LCA- based data and supporting information are confirmed.

As the External Independent Third-Party Reviewer, I confirm that I have sufficient knowledge and experience of steel products, the relevant PCR, ISO standards and the geographical areas intended to generate EPDs to carry out this verification.

Sincerely,

A handwritten signature in black ink that reads "Rifat A. Karim".

Name : Rifat A. Karim

Title : President

Organization : ARII Environmental Services LLC.