EPD Background Report

Hollow Structural Sections

On behalf of the Steel Tube Institute

July 2021

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On behalf of Sphera Solutions, Inc. and its subsidiaries

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List of Acronyms

ADP	Abiotic Depletion Potential
AISI	American Iron and Steel Institute
AP	Acidification Potential
EoL	End-of-Life
EP	Eutrophication Potential
GaBi	Ganzheitliche Bilanzierung (German for holistic balancing)
GHG	Greenhouse Gas
GWP	Global Warming Potential
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LHV	Lower Heating Value
NMVOC	Non-Methane Volatile Organic Compound
ODP	Ozone Depletion Potential
SFP	Smog Formation Potential
STI	Steel Tube Institute
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
VOC	Volatile Organic Compound

Glossary

Life Cycle

A view of a product system as “consecutive and interlinked stages … from raw material acquisition or generation from natural resources to final disposal” (ISO 14040:2006, section 3.1). This includes all material and energy inputs as well as emissions to air, land and water.

Life Cycle Assessment (LCA)

“Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle” (ISO 14040:2006, section 3.2)

Life Cycle Inventory (LCI)

“Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle” (ISO 14040:2006, section 3.3)

Life Cycle Impact Assessment (LCIA)

“Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product” (ISO 14040:2006, section 3.4)

Life Cycle Interpretation

“Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations” (ISO 14040:2006, section 3.5)

Functional Unit

“Quantified performance of a product system for use as a reference unit” (ISO 14040:2006, section 3.20)

Allocation

“Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems” (ISO 14040:2006, section 3.17)

Closed-loop and Open-loop Allocation of Recycled Material

“An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties.”

“A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials.”

(ISO 14044:2006, section 4.3.4.3.3)

Foreground System

“Those processes of the system that are specific to it … and/or directly affected by decisions analyzed in the study.” (JRC 2010, p. 97) This typically includes first-tier suppliers, the manufacturer itself and any downstream life cycle stages where the manufacturer can exert significant influence. As a general rule, specific (primary) data should be used for the foreground system.

Background System

“Those processes, where due to the averaging effect across the suppliers, a homogenous market with average (or equivalent, generic data) can be assumed to appropriately represent the respective process … and/or those processes that are operated as part of the system but that are not under direct control or decisive influence of the producer of the good….” (JRC 2010, pp. 97-98) As a general rule, secondary data are appropriate for the background system, particularly where primary data are difficult to collect.

1. Goal of the Study

Aware of the increasing demand for the reporting of a product's environmental performance, the Steel Tube Institute (STI) is interested in demonstrating their sustainability leadership and leverage business value in the steel industry. Thus, STI commissioned Sphera Solutions, Inc (Sphera) to update its environmental product declaration (EPD) for hollow structural sections (HSS) manufactured in North America by STI members.

This analysis was conducted according to UL Environment's (ULE) Product Category Rules (PCR) *Part A: Life Cycle Assessment Calculation Rules and Report Requirements* and *Part B: Designated Steel Construction Product EPD Requirements* (UL Environment, 2018; UL Environment, 2020).The intended audience for this report includes the program operator, ULE, the reviewer who will be assessing the life cycle assessment (LCA) for conformance to the PCR, STI, and its member companies. The EPD is intended for business-to-business communication. Company-specific information has been aggregated to create a production volume-weighted, industry average based on product mass and production volume. Therefore, confidential information specific to each company is not disclosed in this report.

Results presented in this document do not constitute comparative assertions. Please refer to the disclaimer in the EPDs with regard to the comparability of EPDs.

This study was commissioned by STI and performed by Sphera. The study has been conducted in accordance with the International Standard ISO 14044. Conformance of the background LCA study as well as the final EPD with the guiding PCR and ISO 14025, ISO 21930, ISO 14040, and ISO 14044 were verified through ULE's EPD program.

2. Scope of the Study

The following sections describe the general scope of the project to achieve the stated goals. This includes, but is not limited to, the identification of specific product systems to be assessed, the product function(s), functional unit and reference flows, the system boundary, allocation procedures, and cut-off criteria of the study.

2.1. Product Systems

Hollow structural sections are typically used in buildings, bridges, and industrial applications. This declaration covers the market average of HSS, produced in the North America by STI members.

The following CSI and UNSPSC codes may correspond to the declared product.

- 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

Hollow structural sections products are defined by the following ASTM standards.

- ASTM A500: Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
- ASTM A513: Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing
- ASTM A847: Standard Specification for Cold-Formed Welded and Seamless High-Strength, Low-Alloy Structural Tubing with Improved Atmospheric Corrosion Resistance
- ASTM A1085: Standard Specification for Cold-Formed Welded Carbon Steel Hollow Structural Sections (HSS)

Steel pipe piles and steel pipe are also included in the declaration as the same materials and processes are used to manufacture these products. Steel pipe piles and steel pipe products are defined by the following ASTM standards:

- ASTM A135: Standard Specification for Electric-Resistance-Welded Steel Pipe
- ASTM A252: Standard Specification for Welded and Seamless Steel Pipe Piles
- ASTM A53: Standard Specification for Pipe
- ASTM A795: Standard Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection
- CSA G40.21: General requirements for rolled or welded structural quality steel

2.2. Declared Unit

A declared unit is used in place of a functional unit due to the wide variety of material characteristics, designs and applications for steel construction products covered by the PCR. Declared units are defined under ISO 21930 (ISO, 2017) and permitted for information modules, for which only a subset of life cycle stages are included in the analysis.

The declared unit evaluated for this study is:

1 metric ton (1 tonne or 1,000 kg) of steel products.

Environmental performance results therefore represent the industry average production of HSS, normalized to 1 metric ton. The reference service life is not specified. Because the use stage is not included in the system boundary, no reference service life needs to be defined for the analysis.

2.3. System Boundaries

This study considers the cradle-to-gate production (A1-A3) of steel products. That is, it includes the potential environmental impacts associated with the extraction of resources from nature through to the point at which the finished product is ready to leave the producer gate.

Fabrication (A3), transportation to the job site (A4), construction (A5), the use stage (B1-B7), the disposal stage (C1-C4), and benefits and loads beyond the system boundary (D) are excluded from the LCA and EPD scope.

Table 2-1: System boundaries

Included	Excluded
✓ Raw material production, including steelmaking (A1) ✓ Inbound transportation of raw materials (A2) ✓ HSS manufacturing (A3) ✓ Treatment of wastes from HSS manufacturing (A3)	× Capital goods and infrastructure × Employee commute × Product packaging materials × Downstream life cycle stages: × Fabrication (A3) × Distribution (A4) × Installation (A5) × Use (B1-B7) × End-of-Life (C1-C4) × Recycling/recovery credit or burden at End-of-Life (D)

Production and maintenance of capital goods and infrastructure have been excluded from the study. It is expected that these impacts are negligible compared to the impacts associated with running the equipment over its operational lifetime. Any activities downstream of the cradle-to-gate system boundary of the steel products are likewise excluded.

2.3.1. Time Coverage

The analysis is intended to represent HSS production for the reference year 2020. Production data was collected for the years 2019-2020.

2.3.2. Technology Coverage

The study is intended to represent an industry-average environmental profile of the participating STI member companies' technologies and their supply chains. Data on material inputs and manufacturing are primary data from the individual member companies.

2.3.3. Geographical Coverage

The analysis is intended to represent HSS production in North America. Data is intended to represent the North American technology. Data for hot-rolled coil, cold-rolled coil and hot-dip galvanized coil production are based on industry data from the American Iron and Steel Institute (AISI) and worldsteel. Participating STI members are listed in Annex A.

2.4. Allocation

2.4.1. Multi-output Allocation

No multi-output allocation was required in the foreground system of the study.

Allocation of background data (energy and materials) taken from the GaBi 2021 databases is documented online at https://sphera.com/wp-content/uploads/2020/04/Modeling-Principles-GaBi-Databases-2021.pdf. Background data for steelmaking from AISI and worldsteel use the system expansion allocation method for co-products from the steelmaking process.

2.4.2. End-of-Life Allocation

Since the EPD does not cover the end-of-life of the products, end-of-life allocation is outside the scope of the study. Metal scrap from manufacturing (module A3) was balanced with the scrap demand of the raw materials module (A1) in order to calculate the net scrap input to module A1.

Under a cradle-to-gate system boundary, scrap inputs to the system are not associated with any upstream burden, and scrap produced during manufacturing is assumed to be at least the same quality as scrap inputs into steelmaking. Remelting of scrap to produce structural steel and other raw materials is accounted for within module A1 using upstream datasets.

2.5. Cut-off Criteria

In lieu of arbitrary cut-off criteria, all available energy and material flow data were included in the model for processes within the system boundary.

In cases where no matching life cycle inventories were available to represent a flow, proxy data were applied based on conservative assumptions regarding environmental impacts. The choice of proxy data is documented in section 3.4.

2.6. Selection of LCIA Methodology and Impact Categories

The impact assessment categories and other metrics required by the PCR are shown in Table 2-2. GWP excludes biogenic carbon as there are no relevant bio-based raw materials present in the product, and therefore the impacts of biogenic carbon on the results are expected to be several orders of magnitude smaller than the reported results.

Table 2-2: Required declaration of environmental impacts, use of resources, and generation of waste

Indicator	Unit	Methodology
Life Cycle Impact Assessment Results		

Indicator	Unit	Methodology
Global warming potential, excluding biogenic carbon, 100-year time frame (GWP 100)	kg CO_2 eq	IPCC AR5 (IPCC, 2013)
Ozone depletion potential (ODP)	kg CFC-11 eq	TRACI 2.1 (Bare, 2012) (EPA, 2012)
Acidification potential (AP)	kg SO_2 eq	
Eutrophication potential (EP)	kg N eq	
Smog formation potential (SFP)	kg O_3 eq	
Abiotic resource depletion potential of non-renewable (fossil) energy resources (ADP_{fossil})	MJ	
Resource Use		
Renewable primary resources used as energy carrier (fuel) (RPR_E)	MJ LHV	ISO 21930 (ISO, 2017), informed by the ACLCA Guidance document (ACLCA, 2019)
Renewable primary resources with energy content used as material (RPR_M)	MJ LHV	
Non-renewable primary resources used as an energy carrier (fuel) ($NRPR_E$)	MJ LHV	
Non-renewable primary resources with energy content used as material ($NRPR_M$)	MJ LHV	
Secondary materials (SM)	kg	
Renewable secondary fuels (RSF)	MJ LHV	
Non-renewable secondary fuels (NRSF)	MJ LHV	
Recovered energy (RE)	MJ LHV	
Use of net fresh water resources (FW)	m^3	
Output Flows and Waste Categories		
Hazardous waste disposed (HWD)	kg	ISO 21930 (ISO, 2017), informed by the ACLCA Guidance document (ACLCA, 2019)
Non-hazardous waste disposed (NHWD)	kg	
High-level radioactive waste, conditioned, to final repository (HLRW)	kg	
Intermediate- and low-level radioactive waste, conditioned, to final repository (ILLRW)	kg	
Components for re-use (CRU)	kg	
Materials for recycling (MR)	kg	
Materials for energy recovery (MER)	kg	
Recovered energy exported from the product system (EE)	MJ LHV	

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

2.7. Interpretation to be Used

The results of the LCI and LCIA were interpreted according to the Goal and Scope. The interpretation addresses the following topics:

- Identification of significant findings, such as the main process step(s), material(s), and/or emission(s) contributing to the overall results
- Evaluation of completeness, sensitivity, and consistency to justify the exclusion of data from the system boundaries as well as the use of proxy data.
- Conclusions, limitations and recommendations

2.8. Data Quality Requirements

The data used to create the inventory model shall be as precise, complete, consistent, and representative as possible with regards to the goal and scope of the study under given time and budget constraints.

- Measured primary data are considered to be of the highest precision, followed by calculated data, literature data, and estimated data. The goal is to model all relevant foreground processes using measured or calculated primary data.
- Completeness is judged based on the completeness of the inputs and outputs per unit process and the completeness of the unit processes themselves. The goal is to capture all relevant data in this regard.
- Consistency refers to modeling choices and data sources. The goal is to ensure that differences in results reflect actual differences between product systems and are not due to inconsistencies in modeling choices, data sources, emission factors, or other artefacts.
- Reproducibility expresses the degree to which third parties would be able to reproduce the results of the study based on the information contained in this report. The goal is to provide enough transparency with this report so that third parties are able to approximate the reported results. This ability may be limited by the exclusion of confidential primary data and access to the same background data sources
- Representativeness expresses the degree to which the data matches the geographical, temporal, and technological requirements defined in the study's goal and scope. The goal is to use the most representative primary data for all foreground processes and the most representative industry-average data for all background processes. Whenever such data were not available (e.g., no industry-average data available for a certain country), best-available proxy data were employed.

An evaluation of the data quality with regard to these requirements is provided in Chapter 5 of this report.

2.9. Type and Format of the Report

In accordance with the ISO requirements (ISO, 2006) this document aims to report the results and conclusions of the LCA completely, accurately and without bias to the intended audience. The results, data, methods, assumptions and limitations are presented in a transparent manner and in sufficient detail to convey the complexities, limitations, and trade-offs inherent in the LCA to the reader. This allows the results to be interpreted and used in a manner consistent with the goals of the study.

2.10. Software and Database

The LCA model was created using the GaBi 10 Software system for life cycle engineering, developed by Sphera Solutions, Inc. The GaBi 2021 LCI database (CUP 2021.1) provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

2.11. EPD Verification

The EPD development process requires verification by an independent verifier. Report verification was conducted by James Mellentine, Thrive ESG on behalf of ULE. Verification was conducted in accordance with ISO 14025, ISO 14040, ISO 14044, and ISO 21930 requirements and the PCR (UL Environment, 2018; UL Environment, 2020).

3. Life Cycle Inventory Analysis

3.1. Data Collection Procedure

Primary data were collected using data collection templates customized by Sphera. The templates were sent out by email to the respective data providers at the participating sites. Upon receipt, each questionnaire was cross-checked for completeness and plausibility using mass balance, stoichiometry, as well as internal and external benchmarking. If gaps, outliers, or other inconsistencies occurred, Sphera engaged with the data provider to resolve any open issues.

Data collection represents annual production in in 2019 and 2020 for HSS. Facility-specific data was combined to create an average product using annual production total by mass.

3.2. Overview of Product System

The cradle-to-gate life cycle inventory of HSS products is developed in this analysis, as illustrated in Figure 3-1.

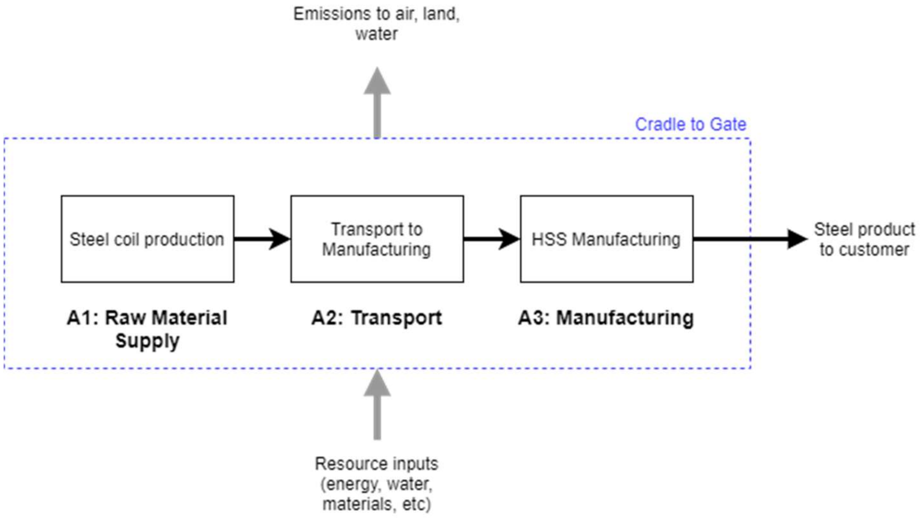

Figure 3-1: System boundary

Module A1 represents steelmaking, module A2 represents transportation of steel coil to HSS manufacturing, and module A3 represents HSS manufacturing. The manufacturing process includes use of energy and ancillary materials, direct emissions, and processing of wastes. All of the steel required to satisfy the declared unit, including steel that ends up as scrap during the HSS manufacturing process, is included under module A1.

3.3. HSS Production

Hollow structural sections are manufactured by cold-forming steel coil into tubes. Hot-rolled coil is first slit into sections of appropriate width. The narrower coils are then uncoiled and passed through a series of rollers that form the continuous sheet into tubes. Tube cross-sections can be rectangular, round, or elliptical, depending upon the intended application. The two edges of the coil are welded together via an electric resistance welding process and the product is then cut to length. Once manufactured, HSS can be powder coated or primed—or left uncoated. The tubes are subsequently packaged for shipment.

The primary input to HSS production is the steel itself, although small amounts of process and coating materials are needed. Electricity is used for manufacturing and to move the materials. Manufacturing produces some metal scrap. The scrap generated during manufacturing is assumed to be produced at the same quality as used by the upstream metal production processes. Therefore, the scrap from manufacturing is treated assuming open-loop recycling.

3.3.1. Product Composition

Steel HSS products are made of carbon steel with a small percentage of alloy elements and paints included. 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.

3.3.2. Unit Process

Table 3-1 provides details on the unit process modeled for this LCI. The unit process data is calculated as a weighted average of HSS production by study participants.

Table 3-1: Unit process data for 1 metric ton of HSS

I/O	Flow	Units	Weighted average	10th percentile	90th percentile
Inputs	Steel				
	Hot rolled coil	kg	1.03E+03	9.70E+02	1.10E+03
	Cold rolled coil	kg	1.08E+01	1.50E+01	1.22E+02
	Hot-dip galvanized coil	kg	1.68E+00	4.53E+00	2.73E+01
	Ancillary materials				
	Acetylene	kg	1.96E-03	7.55E-04	9.14E-03
	Argon	kg	5.16E-03	3.53E-04	2.04E-02
	Carbide blades	kg	2.59E-02	2.58E-03	5.46E-02
	Cleaning chemicals	kg	7.02E-01	1.49E-01	2.06E+01
	Coolant	kg	4.33E-01	1.50E-01	6.55E-01
	Ethylenediaminetetraacetic acid	kg	6.41E-03	6.22E-03	1.41E-01
	Lubricants	kg	1.44E-01	1.67E-02	3.68E-01
	Oxygen	kg	7.08E-03	4.09E-03	3.84E-02
	Paint	kg	2.82E-01	2.46E-03	2.26E+00
	Rust prevention oil	kg	3.50E-02	1.45E-03	1.44E-01
	Slitter knives	kg	4.72E-03	3.60E-03	3.19E-02
	Welding electrodes	kg	7.46E-04	7.46E-04	7.99E-03
	Welding wire	kg	1.26E-02	6.14E-03	3.28E-02

I/O	Flow	Units	Weighted average	10th percentile	90th percentile
	Energy				
	Electricity	MJ	2.18E+02	1.08E+02	3.97E+02
	Diesel, internal transport	kg	2.80E-02	1.46E-02	1.47E-01
	Gasoline, internal transport	kg	2.16E-03	1.05E-03	2.18E-02
	Propane, internal transport	kg	1.79E-02	1.39E-02	6.44E-02
	Thermal energy from natural gas	MJ	3.41E+02	1.13E+01	3.92E+02
	Water				
	Municipal water	kg	1.74E+01	2.82E-01	6.44E+01
	River water	kg	1.53E+01	6.95E+01	5.03E+02
Outputs	**Product**				
	Hollow structural sections	kg	1.00E+03	-	-
	Materials for recovery				
	Steel scrap	kg	5.70E+01	1.33E+01	1.28E+02
	Manufacturing waste	kg	1.36E+01	2.91E+00	3.40E+01
	Wastes for disposal				
	Non-hazardous manufacturing waste	kg	5.86E+00	5.08E-02	2.23E+01
	Hazardous manufacturing waste	kg	1.54E-01	7.71E-04	1.76E+00
	Water to municipal treatment	kg	9.12E-01	1.57E-02	1.41E+01
	Water treated on-site and discharged	kg	2.05E+01	5.77E+00	6.01E+02
	Emissions to air				
	Nitrogen oxides	kg	1.23E-02	5.60E-02	4.06E-01
	Dust (PM10)	kg	6.43E-03	9.54E-03	1.48E-01
	NMVOCs	kg	2.94E-02	5.04E-03	2.13E-01
	Water vapor	kg	1.13E+01	1.39E-01	2.76E+01

* The weighted average takes into account all reported data, including cases where the value for an input or output is zero for a facility. The 10th/90th percentiles are calculated excluding those zero values.

3.4. Background data

Documentation for all GaBi datasets can be found at http://www.gabi-software.com/america/support/gabi/.

3.4.1. Fuels and Energy

National and regional averages for fuel inputs and electricity grid mixes were obtained from the GaBi 2021 databases. Table 3-2 shows the most relevant LCI datasets used in modeling the product systems. Electricity consumption was modeled using regional grid mixes that account for imports from neighboring regions. The “Proxy?” column indicates whether a dataset is a geographical or a technological proxy.

Table 3-2: Key energy datasets used in inventory analysis

Energy	Geographic Reference	Dataset	Data Provider	Ref. Year	Proxy?*
Electricity					
Canada	CA	Electricity grid mix	Sphera	2017	No
CAMX	US	Electricity grid mix – CAMX	Sphera	2018	No
NWPP	US	Electricity grid mix – NWPP	Sphera	2018	No
RFCM	US	Electricity grid mix – RFCM	Sphera	2018	No
RFCW	US	Electricity grid mix – RFCW	Sphera	2018	No
SRMV	US	Electricity grid mix – SRMV	Sphera	2018	No
SRSO	US	Electricity grid mix – SRSO	Sphera	2018	No
SRTV	US	Electricity grid mix – SRTV	Sphera	2018	No
Technical heat					
Natural gas	US	Thermal energy from natural gas	Sphera	2017	No
Diesel	US	Thermal energy from diesel	Sphera	2017	No
Gasoline	US	Thermal energy from gasoline	Sphera	2017	No
Propane	US	Thermal energy from propane	Sphera	2017	No

* No = no proxy used; Tech. = technological proxy; Geo. = geographic proxy

3.4.2. Raw Materials and Processes

Data for raw materials were obtained from the GaBi 2021 databases. Table 3-3 shows the LCI datasets used for modeling steel and Table 3-4 includes datasets for manufacturing materials and processes. The "Proxy?" column indicates whether a dataset is a geographical or a technological proxy.

Table 3-3: Steel datasets used in inventory analysis

Material / Process	Geographic Reference	Dataset	Data Provider	Ref. Year	Proxy?*
Hot rolled coil	Asia	Steel hot rolled coil	worldsteel	2019	No
Hot rolled coil	GLO	Steel hot rolled coil	worldsteel	2019	No
Hot rolled coil	RNA	Steel hot rolled coil	AISI	2017	No
Cold rolled coil	GLO	Steel cold rolled coil	worldsteel	2019	No
Cold rolled coil	RNA	Steel cold rolled coil	AISI	2017	No
Hot-dip galvanized coil	RNA	Steel hot dip galvanised	AISI	2017	No

Table 3-4: Key manufacturing datasets used in inventory analysis

Material / Process	Geographic Reference	Dataset	Data Provider	Ref. Year	Proxy?*
Process materials					
Acetylene	US	Ethyne (acetylene)	Sphera	2020	No
Argon	US	Argon (gaseous)	Sphera	2020	No
Carbide blades	RNA	Steel cold rolled coil	AISI	2017	Tech.
Coolant	DE	Thiazole (2-Mercaptobenzothiazol, C7H5NS2)	Sphera	2020	Geo.
Lubricants	US	Lubricants at refinery	Sphera	2017	No
Oxygen	US	Oxygen (gaseous)	Sphera	2020	No
Paint	DE	Solvent paint white (EN15804 A1-A3)	Sphera	2020	Geo.
Rust prevention oil	US	Naphtha at refinery	Sphera	2017	No
Welding wire	DE	Steel wire rod	Sphera	2020	Geo. Tech.
Welding electrodes	RNA	Steel cold rolled coil	AISI	2017	No
	EU-28	Ferrous oxide (FeO) (via iron)	Sphera	2019	Geo.
	ZA	Ferro-manganese, refined (Ref. FeMn), 80 to 85 wt. % Mn, less than 1.5 wt % carbon	Sphera	2019	No
	GLO	Ferro silicon mix (90% Si)	Sphera	2020	No
	US	Silica sand (flour)	Sphera	2020	No
	US	Fluorspar (extraction and processing)	Sphera	2020	No
	DE	Cryolite (estimation)	Sphera	2020	Geo.
	US	Titanium dioxide pigment (sulphate process)	Sphera	2020	No
	DE	Water glass (Sodium silicate)	Sphera	2020	Geo.
Municipal water	US	Tap water from groundwater	Sphera	2020	No
Waste processing					
Hazardous waste	US	Hazardous waste (statistical average) (C rich, worst case scenario incl. landfill)	Sphera	2020	No
Non-hazardous waste	US	Glass/inert on landfill	Sphera	2020	No
Wastewater treatment	US	Municipal waste water treatment (mix)	Sphera	2020	No

* No = no proxy used; Tech. = technological proxy; Geo. = geographic proxy

3.4.3. Transportation

Average transportation distances and modes of transport are included for the transport of the raw materials, operating materials, and auxiliary materials to manufacturing facilities. The GaBi 2021 databases were used to model transportation.

Table 3-5: Transportation datasets used in the inventory

Transport/Fuel	Geographic Reference	Dataset name	Data Provider	Ref. Year	Proxy?*
Mode					
Ship	GLO	GLO: Bulk commodity carrier, average, ocean going Sphera <u-so>	Sphera	2020	No
Rail	GLO	GLO: Rail transport cargo - average, average train, gross tonne weight 1,000t / 726t payload capacity	Sphera	2020	No
Truck	US	US: Truck - heavy/bulk (EPA SmartWay)	Sphera	2020	No
Fuel					
Diesel	US	US: Diesel mix at filling station	Sphera	2017	No
Fuel oil	US	US: Heavy fuel oil at refinery (2.5w.% S)	Sphera	2017	No

* No = no proxy used; Tech. = technological proxy; Geo. = geographic proxy

4. LCIA Results

This chapter contains the results for the impact categories and inventory metrics defined in section 2.6. It shall be reiterated at this point that the reported impact categories represent impact potentials, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen functional unit (relative approach).

LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

4.1. Hollow Structural Sections

Results are presented in this section for 1 metric ton of HSS. Table 4-1 presents resource use, Table 4-2 shows waste outputs, and Table 4-3 presents LCIA results.

Table 4-1: Weighted average resource use for 1 metric ton of hollow structural sections

Indicator	Unit	Total	A1	A2	A3
RPR_e	MJ	9.09E+02	7.97E+02	8.68E+00	1.03E+02
RPR_m	MJ	-	-	-	-
$NRPR_e$	MJ	2.19E+04	2.06E+04	2.16E+02	1.07E+03
$NRPR_m$	MJ	1.82E-01	-	-	1.82E-01
SM	kg	4.84E+02	4.84E+02	-	2.44E-02
RSF	MJ	-	-	-	-
NRSF	MJ	-	-	-	-
RE	MJ	-	-	-	-
FW	m^3	9.46E+00	9.29E+00	3.70E-02	1.30E-01

Table 4-2: Weighted average output flows and wastes for 1 metric ton of hollow structural sections

Indicator	Unit	Total	A1	A2	A3
HWD	kg	1.54E-01	-	-	1.54E-01
NHWD	kg	5.87E+00	-	-	5.87E+00
HLRW	kg	7.94E-04	7.28E-04	7.27E-07	6.52E-05
ILLRW	kg	6.63E-01	6.08E-01	6.12E-04	5.45E-02
CRU	kg	-	-	-	-
MR	kg	7.05E+01			7.05E+01
MER	kg	-	-	-	-
EE	MJ	-	-	-	-

Table 4-3: Weighted average LCIA results for 1 metric ton of hollow structural sections

Indicator	Unit	Total	A1	A2	A3
GWP	kg CO2 eq.	1.71E+03	1.64E+03	1.51E+01	6.23E+01
ODP*	kg CFC 11 eq.	-2.17E-12	-2.39E-12	3.04E-15	2.18E-13
AP	kg SO2 eq.	3.71E+00	3.52E+00	1.01E-01	9.14E-02
EP	kg N eq.	1.91E-01	1.72E-01	8.47E-03	1.02E-02
SFP	kg O3 eq.	6.38E+01	5.86E+01	3.24E+00	1.98E+00
ADP_{fossil}	MJ, surplus	1.49E+03	1.35E+03	2.87E+01	1.07E+02

* ODP has limited relevance due to the absence of ozone-depleting emissions in the LCI, in both the background and foreground data. ODP for A1 is negative due to crediting in the background data for steel coil from AISI.

Per the PCR, "industry average EPDs shall report information on the statistical distribution of results for all TRACI indicators". The min and max results presented in Table 4-4 represent the facilities with the lowest (best) and highest (worst) impacts, respectively. Min and max facilities are determined for each impact category separately. The mean and median do not take production volumes across facilities into account (i.e., it is a calculation based on each individual facility as a data point), while the weighted average presented in Table 4-3 is calculated via production volume weightings reported by each participating facility.

Table 4-4: Statistical metrics of LCIA results for 1 metric ton of hollow structural sections across all facilities

Indicator	Unit	Min (A1-A3)	Max (A1-A3)	Max/Min Ratio (A1-A3)	Mean (A1-A3)	Median (A1-A3)
GWP	kg CO2 eq.	1.55E+03	2.76E+03	1.79E+00	1.77E+03	1.71E+03
ODP	kg CFC 11 eq.	-2.54E-12	1.04E-13	-4.07E-02	-1.99E-12	-2.27E-12
AP	kg SO2 eq.	3.29E+00	5.11E+00	1.55E+00	3.84E+00	3.76E+00
EP	kg N eq.	1.65E-01	3.98E-01	2.41E+00	2.02E-01	1.89E-01
SFP	kg O3 eq.	5.53E+01	9.59E+01	1.73E+00	6.62E+01	6.35E+01
ADP_{fossil}	MJ, surplus	1.29E+03	3.64E+03	2.82E+00	1.56E+03	1.41E+03

4.2. Contribution Analysis by Life Cycle Stage

The relative contribution of each life cycle stage to the overall cradle-to-gate LCIA results are presented in Figure 4-1. The vast majority of the potential environmental impacts is driven by the upstream burdens of steelmaking, therefore A1 is the dominant contributor across LCIA indicators.

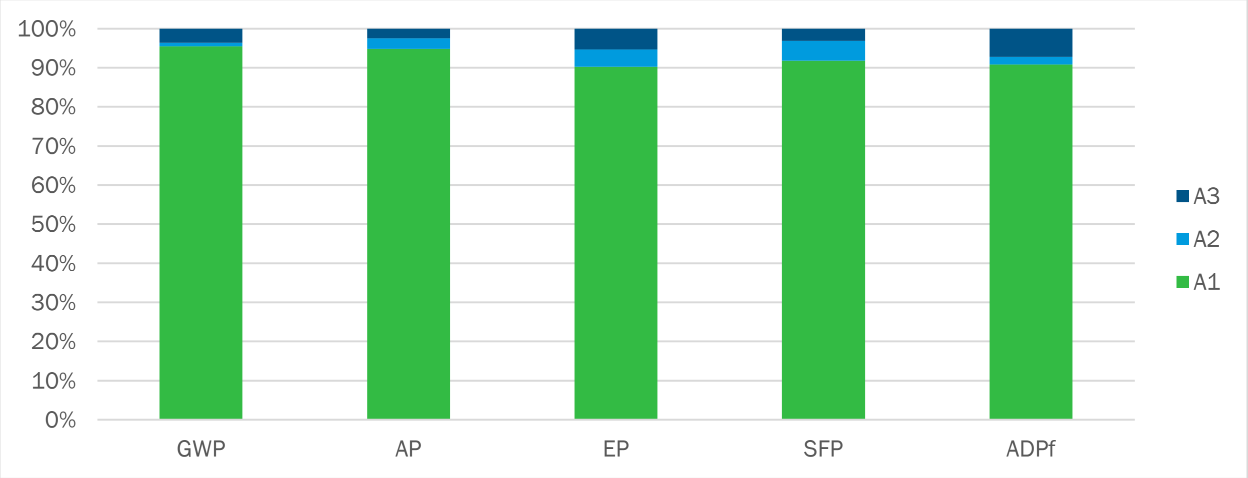

Figure 4-1: Relative contribution by life cycle stage for 1 metric ton of hollow structural steel sections

4.3. Analysis by Manufacturing Component

To better understand sources of potential environmental impacts within the manufacturing process, Figure 4-2 presents relative results broken down by manufacturing components. Potential environmental impacts for HSS manufacturing are dominated by upstream burdens of steelmaking. ODP for steel inputs is negative due to crediting in the background data for steel coil from AISI.

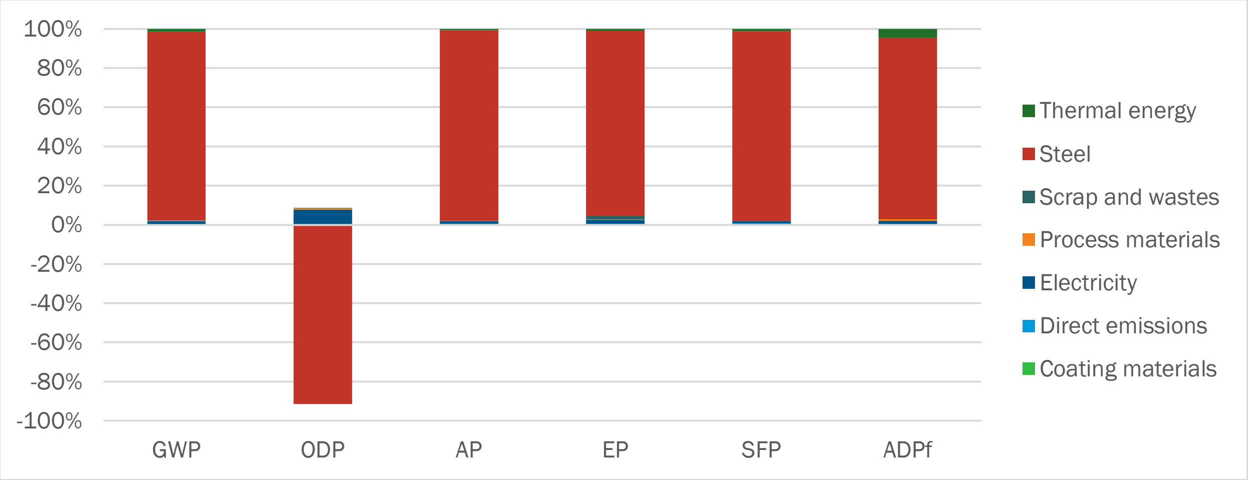

Figure 4-2: Relative contribution of manufacturing components for 1 metric ton of hollow structural steel sections

5. Interpretation

5.1. Identification of Relevant Findings

The cradle-to-gate potential environmental impacts of HSS products are driven by steel coil production (A1). Inbound transport to manufacturing (A2) and HSS manufacturing (A3) contribute to potential environmental impacts on a smaller order of magnitude.

5.2. Assumptions and Limitations

The HSS inventory data was collected by participating STI member companies to represent HSS manufacturing in North America. Where inbound transportation data was incomplete, a distance of 500 miles by truck was used.

Proxy data were applied to some materials where no matching life cycle inventories were available as documented in section 3.4.

5.3. Data Quality Assessment

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

To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the GaBi 2021 database were used. The LCI datasets from the GaBi 2021 database are widely distributed and used with the GaBi 10 Software. The datasets have been used in LCA models worldwide in industrial and scientific applications in internal as well as in many critically reviewed and published studies. In the process of providing these datasets they are cross-checked with other databases and values from industry and science.

5.3.1. Precision and Completeness

- ✓ **Precision:** As the majority of the relevant foreground data are measured data or calculated based on primary information sources of the owner of the technology, precision is considered to be high. Variations in the data were balanced out by using yearly averages of data from multiple sites. All background data are sourced from GaBi databases with the documented precision.
- ✓ **Completeness:** Each foreground process was checked for mass balance and completeness of the emission inventory. No data were knowingly omitted from the model. Data gaps, particularly for transportation, were filled whenever possible. Completeness of foreground unit process data is considered to be acceptable. All background data are sourced from GaBi databases with the documented completeness.

5.3.2. Consistency and Reproducibility

- ✓ **Consistency:** To ensure data consistency, all primary data were collected using the same data questionnaires and data gaps filled to the best of Sphera's abilities. All background data were sourced from the GaBi databases.
- ✓ **Reproducibility:** Reproducibility is supported as much as possible through the disclosure of input-output data, dataset choices, and modeling approaches in this report. Based on this information, any third party should be able to approximate the results of this study using the same data and modeling approaches.

5.3.3. Representativeness

- ✓ **Temporal:** All primary data were collected for 2019-2020. All secondary data come from the GaBi 2021 databases and are representative of the years 2017 to 2020. As the study intended to evaluate the product systems for the reference year 2020, temporal representativeness is considered to be high.
- ✓ **Geographical:** All primary data were collected specific to the countries or regions under study. Background data, where possible, were selected for the appropriate region. Where country-specific or region-specific data were unavailable, proxy data were used (e.g., for alloy materials). Geographical representativeness is considered to be good.
- ✓ **Technological:** All primary and secondary data were modeled to be specific to the technologies or technology mixes under study. Where technology-specific data were unavailable, proxy data were used—in particular, for the rust prevention oil where SDS data was used to find the best dataset match. Datasets for hot-rolled coil, cold-rolled coil and hot-dipped galvanized coil were taken from an industry average production published by AISI. Technological representativeness is considered to be high.

5.4. Model Completeness and Consistency

5.4.1. Completeness

All relevant process steps for each product system were considered and modeled to represent each specific situation. The process chain is considered sufficiently complete and detailed with regard to the goal and scope of this study.

5.4.2. Consistency

All assumptions, methods and data are consistent with each other and with the study's goal and scope. Differences in background data quality were minimized by exclusively using LCI data from the GaBi 2021 databases. System boundaries, allocation rules, and impact assessment methods have been applied consistently throughout the study.

5.5. Conclusions, Limitations, and Recommendations

5.5.1. Conclusions

The goal of this study was to conduct a cradle-to-gate LCA of hollow structural steel in order to update the industry average EPD. This EPD will allow the industry's customers and professionals in the building and construction industry to make better-informed decisions about the potential environmental impacts associated with HSS manufacturing. Overall, the study found that environmental performance is driven primarily by steel coil production.

5.5.2. Limitations

The use of proxies constitutes to limitations to technological/geographical representativeness. Proxy data were used only for ancillary materials, which contribute minimally to potential environmental impacts.

This study is limited to the environmental performance of HSS production from the 8 manufacturers included in the analysis and does not take into account specific uses of the product.

5.5.3. Recommendations

The results show that steel coil production is the largest contributor to the product's environmental impact. As such, STI members should focus their efforts on sourcing steel from mills with low environmental footprints and with transparency or reporting programs in place. Members should also focus on optimizing coil conversion into HSS by reducing scrap rates on their production lines.

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Annex A. Participating Facilities

STI members that provided data for this industry average EPD are listed below.

- Atlas Tube
  - Birmingham, AL
  - Blytheville, AR
  - Chicago, IL
  - Harrow, ON
  - Plymouth, MI
- Maruichi American Corporation
  - Santa Fe Springs, CA
- Maruichi Leavitt Pipe and Tube
  - Chicago, IL
- Maruichi Oregon Steel Tube
  - Portland, OR
- Nucor Tubular Products
  - Birmingham, AL
  - Chicago, IL
  - Decatur, AL
  - Marseilles, IL
  - Trinity, AL
- Searing Industries
  - Cheyenne, WY
  - Rancho Cucamonga, CA
- VEST, Inc.
  - Vernon, CA
- Wheatland Tube
  - Warren, OH
  - Wheatland, PA