



On behalf of the Concrete Reinforcing Steel Institute

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EPD Background Report

Fabricated Steel Reinforcement



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List of Acronyms

ADP	Abiotic Depletion Potential
ADP _{fossil}	Abiotic Depletion Potential (fossil)
AP	Acidification Potential
BF	Blast Furnace
BOF	Basic Oxygen Furnace
CRU	Components for Re-use
EE	Exported Energy
EPD	Environmental Product Declaration
EoL	End-of-Life
EP	Eutrophication Potential
FW	Use of net Fresh Water
GaBi	Ganzheitliche Bilanzierung (German for holistic balancing)
GHG	Greenhouse Gas
GWP	Global Warming Potential
HLRW	High-level radioactive waste, conditioned, to final repository
HWD	Hazardous Waste Disposed
ILLRW	Intermediate- and low-level radioactive waste, conditioned, to final repository
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MER	Materials for Energy Recovery
MFR	Materials for Recycling
NHWD	Non Hazardous Waste Disposed
NMVOC	Non-Methane Volatile Organic Compound
RPR _E	Renewable primary resources used as energy carrier (fuel)
RPR _M	Renewable primary resources with energy content used as material
NRPR _E	Non-renewable primary resources used as an energy carrier (fuel)
NRPR _M	Non-renewable primary resources with energy content used as material
NRSF	Use of Non-renewable Secondary Fuels
ODP	Ozone Depletion Potential
PCR	Product Category Rules



POCP	Photochemical Ozone Creation Potential
RSF	Use of Renewable Secondary Fuels
RSL	Reference Service Life
SM	Use of Secondary Material
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 interest in transparent reporting of a product's environmental performance, the Concrete Reinforcing Steel Institute (CRSI) desired to demonstrate their sustainability leadership and leverage business value through evaluating the environmental profile of fabricated steel reinforcement or "rebar" and communicating the results in an industry-average Environmental Product Declarations (EPD).

Thus, the goal of the study is to assess the "cradle-to-gate" environmental impacts of CRSI membership products for the purpose of creating an environmental product declaration for steel rebar fabricated by members companies in CRSI. This EPD will be an update to CRSI's existing EPD which was published in 2017.

The analysis was conducted according to the UL Environment's 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, ASTM, the reviewer, who will be assessing the life cycle assessment (LCA) for conformance to the product category rule (PCR), and CRSI members and stakeholders involved in marketing and communications, operations, and research and development. For full conformance with section 5.2 of ISO 14044, Sphera recommends this report be made available upon request to all third parties to whom the EPD is communicated (ISO, 2006). Confidential information does not need to be included in the third-party report.

Results presented in this document do not constitute comparative assertions. However, these results will be disclosed to the public in an industry average EPD, which architects and builders will be able to use to compare CRSI's products with similar products presented in other EPDs that follow the same PCR.

This study was commissioned by CRSI and performed by Sphera. The study has been conducted in accordance with the requirements of 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, and ISO 14044 were verified by ASTM.

Use of the EPD is limited to CRSI members. Member names are available online at www.crsi.org/index.cfm/epd.

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

The system under study is cradle-to-gate fabricated reinforcing bar (rebar). The study included the modeling of the upstream rebar input as well as the fabrication of rebar. This declaration covers fabricated steel rebar produced by CRSI member companies in the US.

The steel reinforcing bars included in this study are defined in the following specifications:

- ASTM A615/A615M Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement, or
- ASTM A706/A706M Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement

The products covered by this study are classified under the Construction Specification Institute Masterformat codes below:

- 03 20 00 – Concrete Reinforcing
- 03 21 00 – Reinforcement Bars
- 03 21 11 – Plain Steel Reinforcement Bars

Steel reinforcing bar with coating are excluded from the scope of this study.

The participating mill locations represent approximately 70% of total domestic rebar production.

2.2 Declared Unit

The declared unit evaluated for this study is:

1 metric ton (1 tonne or 1,000 kg) of fabricated steel rebar

A declared unit is used in place of a functional unit due to the wide variety of building designs and applications for steel construction products covered by the PCR. Declared units are defined under ISO 21930 and permitted for information modules, for which only a subset of life cycle stages are included in the analysis. Environmental performance results represent rebar fabricated by CRSI, normalized to 1 metric ton.

Name	Required unit
Declared unit	Metric ton (tonne)
Density	7,800 kg / m ³

NOTE: Comparison of EPD on a mass-basis alone is insufficient and should consider the technical performance of the product

The reference service life is not specified. Because the use stage is not included in system scope (see Section 2.3), no reference service life is necessary for the analysis.

2.3 System Boundary

The study scope includes the product stage (A1 – A3), which is broken down into three modules, as defined by the UL PCR (UL Environment, 2020):

- A1: Steel rebar production
- A2: Inbound transportation
- A3: Fabrication

Table 2-1 summarizes the inclusions and exclusions from the system boundary. The reference service life of each product is not specified, as only modules A1-A3 are included in the study. Transportation to further processing (fabrication) and job site (A4), construction (A5), the use stage (B1-B7) and the disposal stage (C1-C4) are excluded from the LCA and EPD scope.

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. Packaging of the finished products is likewise excluded. Any activities downstream of the cradle-to-gate system boundary of the steel products are also excluded, per the goals of this study.

Table 2-1: System boundaries

Included	Excluded
✓ Raw materials acquisition and processing (A1)	✗ Construction of capital equipment
✓ Inbound transport of raw materials (A2)	✗ Maintenance and operation of support equipment
✓ Steel production and fabrication (A3)	✗ Human labor and employee commute
✓ Emissions to air, water, and soil during manufacturing (A3)	✗ Transportation to job site (A4)
	✗ Construction and installation (A5)
	✗ Use stage (B1-B7)
	✗ Disposal stage (C1-C4)
	✗ Benefits and loads beyond the system boundary (D)

2.3.1 Time Coverage

Primary data collected from CRSI members represent production for 12 continuous months of production between calendar years 2019 and 2020, with the 12-month period varying between companies (see LCA background report for more information). Background datasets for upstream data were obtained from the GaBi 2021 databases and are representative of the years 2017 – 2021.

2.3.2 Technology Coverage

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

2.3.3 Geographical Coverage

This study is intended to represent steel fabrication by CRSI member companies in the United States.

2.4 Allocation

2.4.1 Multi-output Allocation

Co-products during steel mill operations are allocated using a method developed by the World Steel Association and EUROFER (worldsteel and EUROFER, 2014). The methodology takes into the account the way in which changes in inputs and outputs affect the production of co-products. It uses system expansion for the excess BF and BOF gases that leave the product system. The method also takes account of material flows that carry specific inherent properties. This approach is conformant with the PCR and ISO 21930. ISO 21930 takes precedence over EN15804, per the PCR Part A and Part B (UL Environment, 2020; UL Environment, 2018).

Table 2-2: Co-product allocation, mass basis

Flow	% to Steel	% to Slag
Steel inputs	100	0
Slag	0	100
Steel scrap outputs	86.4	13.6
Oxygen	100	0
Carbon dioxide	100	0
All other inputs/outputs	86.4	13.6

Mill outputs such as scale and baghouse dust are handled via the cut-off approach, in line with ISO 21930. 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>

2.4.2 Manufacturing Waste

Treatment of manufacturing waste is allocated entirely to the steel mills following the ‘polluter pays’ principle.

Steel scrap from the melt shop, rolling mill, and other operations is internally recycled by steel mills. While whether a product is associated with a net consumption or generation of internal scrap is calculated by the model, this particular flow is not reported as part of the final LCIs as, from a mill-level perspective, all internal scrap is fed back into the melt shop.

External or purchased scrap, however, is reported as part of the LCIs. This scrap includes scrap from downstream fabrication operations, product end-of-life, and other sources.

2.5 Cut-off Criteria

For the processes within the system boundary, all available energy and material flow data have been included in the model. In cases where no matching life cycle inventories are available to represent a flow, proxy data have been applied based on conservative assumptions regarding environmental impacts.

The choice of proxy data is documented in section 3.3.

2.6 Selection of LCIA Methodology and Impact Categories

The impact assessment categories and other metrics required by the PCR are shown in Table 2-3. GWP excludes biogenic carbon as the scope of the study is cradle-to-gate and there are no relevant bio-based raw materials present.

Table 2-3: Required declaration of environmental impacts, use of resources, and generation of waste

Indicator	Unit	Methodology
Life Cycle Impact Assessment Results		
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, 2021)
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 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 modelling 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 modelling 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 can 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 regarding these requirements is provided in section 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 2021.2) 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 Thomas Gloria, Ph.D., from Industrial Ecology Consultants, on behalf of ASTM. Verification



was conducted in accordance with the 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

All primary data were collected using customized data collection templates which were sent out by email to the data provider at each participating CRSI member company. Upon receipt, the 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.

Five CRSI member companies, i.e., Cascade, Steel Dynamics, Evraz, CMC and Nucor manufacture rebar. Nineteen facilities completed the data collection questionnaires, which represent a single plant's 2020 data to the total company production volume.

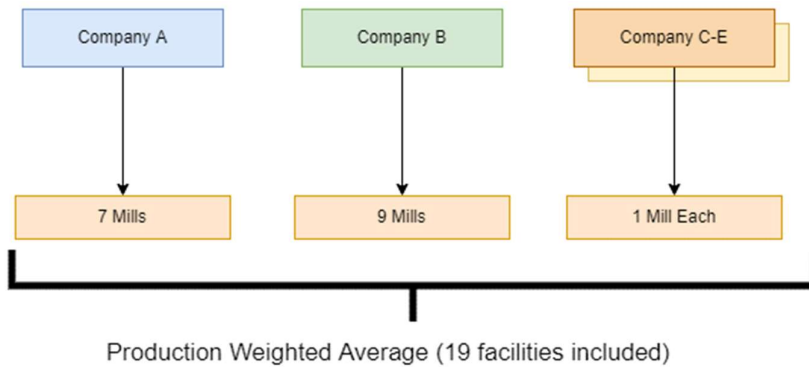


Figure 3-1: Rebar manufacturing facilities

Primary data for fabrication were collected from representative CRSI members via customized questionnaires and represent data for 12 consecutive months between the 2019 and 2020 calendar years, with the selected 12-month period differing between companies, as detailed in Annex B. In total, from within 10 participating companies, 17 facilities completed data collection questionnaires (Figure 3-2).

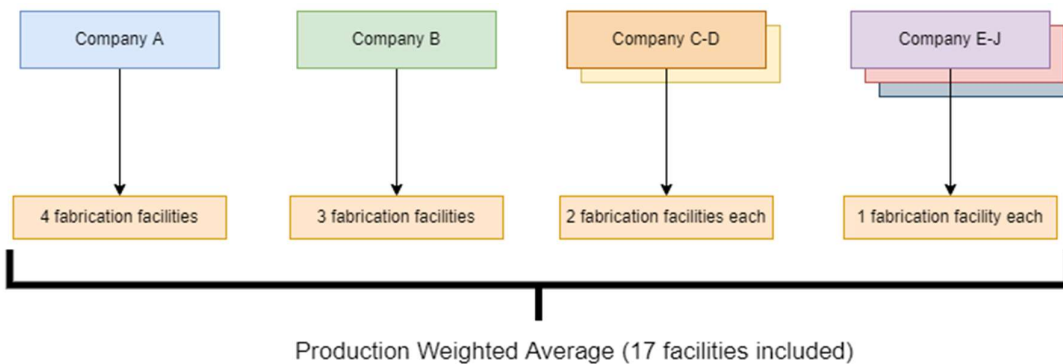


Figure 3-2: Rebar fabrication facilities

3.2 Overview of Product System

The cradle-to-gate life cycle inventories of fabricated reinforcing steel products are included in this analysis.

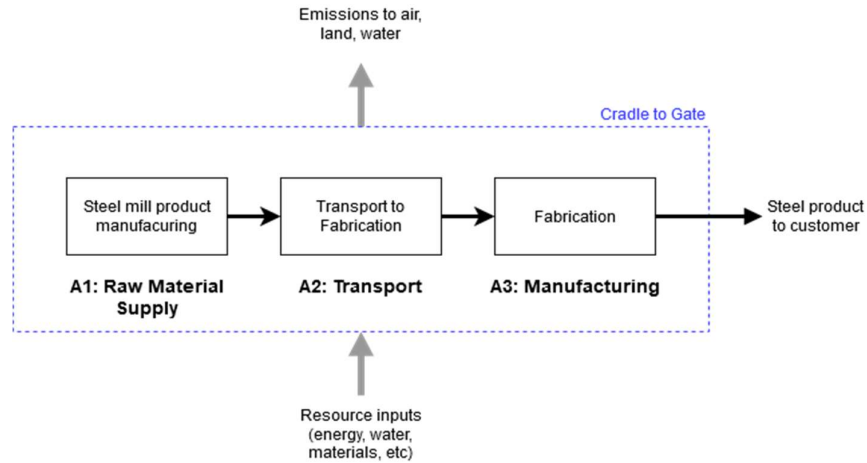


Figure 3-3: Fabricated product system boundary

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

3.2.1 Product Composition

Fabricated steel products are made of steel with a small percentage of alloy elements included which meet the requirements of the following Standard Specification:

- ASTM A615/A615M Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement, or
- ASTM A706/A706M Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement

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.

3.2.2 Manufacturing

The manufacturing processes are described in the section below.

3.2.2.1 Rebar manufacturing

CRSI member companies provided the masses of steel scrap into their facilities, alloy and process material inputs, electricity and fuel consumption, steel rebar output, as well as emissions and wastes from the EAF and rolling mill. Table 3-1 and Table 3-2 summarize the steel rebar production inputs and outputs (including direct emissions) from the melt shop and rolling mill, respectively, necessary for one metric ton of *fabricated* steel rebar (the declared unit). Several additional alloys were modelled as inputs to the melt shop, although only a select number of inputs and outputs is shown in the tables for conciseness.

Table 3-1: Melt shop select unit process inputs and outputs for 1 tonne of fabricated steel rebar (functional unit)

Melt Shop	Value	Units
Inputs		
Steel scrap input	8.03E+02	kg
Home scrap input	4.23E+02	kg
Calcium Carbide	1.71E-01	kg
Calcium Silicon (CaSi)	4.47E-02	kg
Ferrochrome (FeCr)	9.35E-01	kg
Ferrocolumbium (FeCb)	4.03E-05	kg
Ferromanganese (FeMn)	4.86E-02	kg
Ferroniobium (FeNb)	1.39E-03	kg
Ferrosilicon (FeSi)	1.90E+00	kg
Fluorspar	7.44E-01	kg
Nickel	1.58E-03	kg
Silicomanganese (SiMn)	1.40E+01	kg
Vanadium	6.82E-02	kg
Electrolytic Manganese (Mn)	8.32E-03	kg
Ferrovandium	3.07E-02	kg
Anthracite coal	6.12E+00	kg
Charge Carbon	4.85E+00	kg
Coke	9.82E-01	kg
Electrodes	1.93E+00	kg
Injection Carbon	6.51E+00	kg
Lime & Dolomitic Lime	5.12E+01	kg
Refractory Material	5.06E+00	kg
Casting oil	1.41E-02	kg
MgO slag conditioner	4.74E-02	kg
Electricity	6.69E+02	MJ
Natural gas	9.66E+02	MJ
Oxygen	1.81E+01	kg
Argon	3.26E+00	kg
Nitrogen	6.61E+00	kg
Propane (internal transport)	1.66E-02	kg
Oxygen (gaseous)	1.47E+01	kg
River water	2.40E+04	kg
Ground water (on-site well)	4.10E+03	kg
Rain water	2.40E+04	kg
Outputs		
Billets for rebar	1.05E+03	kg
Millscale	2.93E-01	kg
Slag	1.58E+02	kg
Steel scrap (recycled externally, off-site)	3.01E+01	kg
Home scrap	1.05E+01	kg
Baghouse dust (heavy metal content), for recovery	1.40E+01	kg

Baghouse dust (heavy metal content), to landfill	4.27E-01	kg
Refractories	3.53E+00	kg
Sludge from settling ponds (contaminated scale)	0.00E+00	kg
Used oil / lubricant	6.61E-03	kg
Hazardous waste to landfill	1.05E+02	kg
Tunndish Caster Fines	9.57E+00	kg
LRF Dust	3.34E-01	kg
Spent Lime	6.40E-02	kg
Trash	3.71E-01	kg
Used Oil Debris	5.85E-03	kg
Water to municipal treatment	2.80E+04	kg
Water to on-site storage, i.e. settling pond	2.80E+04	kg

Table 3-2: Rolling mill select unit process inputs and outputs for 1 tonne of fabricated steel rebar (functional unit)

Rolling mill	Value	Units
Inputs		
Billets for rebar	1.05E+03	kg
Rollers	1.24E-01	kg
Lubricants	2.30E+00	kg
Electricity	2.93E+02	MJ
Natural gas	5.94E+02	MJ
Outputs		
Rebar	1.00E+03	kg
Millscale	8.21E+00	kg
Steel scrap (recycled externally)	1.37E+01	kg
Home scrap	4.21E+01	kg
Rollers recycled	4.43E-02	kg

3.2.2.2 Rebar fabrication

CRSI members fabricate rebar products at facilities across the United States. The fabrication of rebar includes bending, cutting, and manufacturing of rebar shapes.

CRSI member companies provided the masses of purchased steel rebar and the masses of fabricated rebar output. Collected data for fabrication also included facility energy consumption and ancillary material consumption. For ancillary materials, CRSI member companies provided information such as the lubricants used. Table 3-3 respectively summarize steel rebar fabrication inputs and outputs for one metric ton of product (i.e., the declared unit). Imported rebar was cutoff in the few cases in which it was provided as an input, and the remaining inputs and outputs were scaled accordingly to reflect this cut-off. Data are rounded to three significant digits.

Unit process outputs are detailed in Table 3-3.

Table 3-3: Fabrication unit process inputs and outputs for 1 tonne of fabricated steel rebar (functional unit)

Melt Shop	Value	Units
Inputs		
Steel rebar	1.03E+03	kg

Electricity	2.10E+01	MJ
Natural gas	1.74E+01	kg
Water	7.41E+00	kg
Dunnage	2.57E+00	kg
Diesel	9.59E-01	kg
Steel coupler	7.61E-01	kg
Steel wire	5.57E-01	kg
Lubricant	3.15E-01	kg
Hydraulic oil	2.38E-01	kg
Packaging bagged good	1.16E-01	kg
Wooden pallet	8.42E-02	kg
Steel band	5.93E-02	kg
Propane	4.85E-02	kg
Gasoline	3.70E-02	kg
Corrugated cardboard	6.41E-03	kg
Plastic wrap	4.89E-03	kg
Outputs		
Fabricated rebar	1.00E+03	kg
Steel scrap	3.27E+01	kg
Waste water	6.49E+00	kg
Non-hazardous waste for further processing	9.70E-01	kg
Water vapour	9.18E-01	kg
Used oil	6.94E-01	kg

3.3 Background Data and Literature Used to Conduct the LCA

The background data has been taken from the latest available GaBi database CUP 2021.2. Documentation for all GaBi datasets can be found at <http://www.gabi-software.com/support/gabi/gabi-database-2021-lci-documentation/>.

When assessing the data quality, the level and criteria of the global guidelines of the United Nations for the development of life cycle assessment databases (UN Environment Global Guidance on LCA database development) were applied.

3.3.1 Fuels and Energy

National averages for fuel inputs and electricity grid mixes were obtained from the GaBi 2017 databases. Table 3-4 shows the key life cycle inventory (LCI) datasets used in modeling energy generation and consumption for the product system.

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

Energy	Geographic ref	Dataset name or sub-grid	Source	Ref. year	Proxy?
Electricity	US	US: Electricity grid mix – CAMX	Sphera	2018	No
	US	US: Electricity grid mix – ERCT	Sphera	2018	No
	US	US: Electricity grid mix – FRCC	Sphera	2018	No
	US	US: Electricity grid mix – MROW	Sphera	2018	No

	US	US: Electricity grid mix – NWPP	Sphera	2018	No
	US	US: Electricity grid mix – NYUP	Sphera	2018	No
	US	US: Electricity grid mix – RFCE	Sphera	2018	No
	US	US: Electricity grid mix – SPNO	Sphera	2018	No
	US	US: Electricity grid mix – SRMV	Sphera	2018	No
Fuels	US	Natural gas mix	Sphera	2017	No
	US	Propane at refinery	Sphera	2017	No
	US	Gasoline (regular) mix at filling station	Sphera	2017	No
	US	Diesel mix at filling station	Sphera	2017	No

3.3.2 Raw Materials and Processes

Data for upstream and downstream raw materials and processes were obtained from the GaBi 2021 database and industry association data. Table 3-5 shows the raw material LCI datasets used in modeling the steel rebar production and fabrication.

Table 3-5: Rebar supplier datasets

Raw material	Geographical ref.	Dataset name	Source	Ref. year	Proxy?
Copper	GLO	Copper mix (99.999% from electrolysis)	Sphera	2020	Yes
Ferro-chrome	ZA	Ferro-chrome	Sphera	2020	Yes
Ferro-manganese	ZA	Ferro-manganese	Sphera	2020	Yes
Silico-manganese	ZA	Ferro-manganese	Sphera	2020	Yes
Ferro-silicon	GLO	Ferro-silicon mix	Sphera	2020	Yes
Nickel	GLO	Nickel mix	Sphera	2020	Yes
Sulphur	US	Sulphur (elemental) at refinery	Sphera	2017	No
Aluminum and ferro-aluminum	RNA	Aluminum ingot	Sphera, Aluminum Association	2016	No
Calcium silicon	EU	Calcium silicate	Sphera	2020	Yes
Titanium	GLO	Titanium mix	Sphera	2020	Yes
Calcium carbide	DE	Calcium carbide	Sphera	2019	Yes
Magnesium oxide	EU	Magnesium oxide (MgO, fine, filler)	Sphera	2018	Yes
Fluorspar	US	Fluorspar (import mix)	Sphera	2019	No
Vanadium and ferro-vanadium	ZA	Ferro-vanadium	Sphera	2019	Yes
Ferro-niobium and molybdenum	GLO	Ferro-molybdenum	Sphera	2015	Yes
Boron	DE	Boron trioxide (estimation)	Sphera	2019	Yes
Silicon carbide	DE	Silicon carbide (ESK process)	Sphera	2019	Yes
Anthracite - injection, ladle and charge carbon	US	Hard coal mix	Sphera	2017	No
Dolomite	US	Dolomite (ground)	Sphera	2020	No
Lime quicklime	US	Lime (CaO) calcination	Sphera	2020	No

Refractory material	EU	Fire-proof stones (alumina-rich)	Sphera	2019	Yes
Lubricant	US	Lubricants at refinery	Sphera	2017	No
Electrodes	ZA	Electrode	Sphera	2018	Yes
Argon	US	Argon (gaseous)	Sphera	2020	No
Nitrogen	US	Nitrogen (gaseous)	Sphera	2020	No
Oxygen	US	Oxygen (gaseous)	Sphera	2020	No
Groundwater	US	Tap water from groundwater	Sphera	2018	No
Deionized water	US	Water deionized	Sphera	2020	No
Steel rollers	DE	EAF steel billet / slab / bloom	Sphera	2020	Yes

3.3.3 Transportation

Average transportation distances and modes of transport are included for the transport of the raw materials, operating materials, and auxiliary materials to CRSI member company facilities. The GaBi 2021 database was used to model transportation.

Table 3-6: Transportation datasets used in the inventory

Transport	Geo. ref	Dataset name	Source	Ref. year	Proxy?
Truck	US	Truck – Heavy-duty diesel truck / 53,333 lb payload – 8b	Sphera	2020	No
Freight train	GLO	Rail transport cargo – diesel, light train, gross tonne weight 500t / 363t payload capacity	Sphera	2020	Yes

3.3.4 Manufacturing Waste Treatment

Since use and end-of-life stages are not included in the study's scope, disposal is limited to treatment of manufacturing wastes and recovery of materials. Datasets used for this treatment are summarized in Table 3-7 for both rebar manufacturing and fabrication.

Table 3-7: Disposal datasets used in the inventory

Disposal		Dataset name	Source	Ref. year	Proxy?
Baghouse dust disposal					
EAF dust disposal	GLO	Hazardous waste (non-specific) (C rich, worst case scenario incl. landfill)	Sphera	2018	Yes
Wastewater disposal and treatment chemicals					
Wastewater treatment	US	Municipal waste water treatment (mix)	Sphera	2020	No
Phosphoric acid	US	Phosphoric acid (100%, wet process)	Sphera	2020	No
Acrylonitrile	DE	Acrylonitrile	Sphera	2020	Yes
Hydrochloric acid	DE	Hydrochloric acid mix	Sphera	2020	Yes
Additional disposal					
Disposal of refractory materials, landfill debris, and universal waste	US	Glass/inert on landfill	Sphera	2020	No
Oil incineration	DE	Used oil	Sphera	2020	Yes

4 LCIA Results

This chapter contains the results for the impact categories and additional 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 presented here for fabricated reinforcing steel (rebar) are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

Table 4-1 presents resource use, Table 4-2 shows waste outputs, and Table 4-3 presents LCIA results. Since the treatment of most wastes is included within system boundaries, the amount of waste leaving the mill system is minimal. Any scrap steel generated from fabrication is looped back to upstream steel production.

Table 4-1: Weighted average resource use for 1 metric ton of fabricated steel rebar

Parameter	Unit	A1	A2	A3	A1-A3
RPR _e	MJ	1.13E+03	2.42E+01	2.42E+01	1.17E+03
RPR _m	MJ	-	-	-	-
NRPR _e	MJ	9.06E+03	6.91E+02	1.16E+03	1.09E+04
NRPR _m	MJ	3.04E+02	0.00E+00	0.00E+00	3.04E+02
SM	kg	1.64E+03	0.00E+00	3.54E+01	1.68E+03
RSF	MJ	-	-	-	-
NRSF	MJ	-	-	-	-
RE	MJ	-	-	-	-
FW	m ³	8.25E+00	1.03E-01	6.72E-02	8.42E+00

Table 4-2: Weighted average output flows and wastes for 1 metric ton of fabricated steel rebar

Parameter	Unit	A1	A2	A3	A1-A3
HWD	kg	6.16E-01	0.00E+00	6.94E-01	1.31E+00
NHWD	kg	4.60E+00	0.00E+00	9.71E-01	5.57E+00
HLRW	kg	5.13E-04	1.99E-06	8.00E-06	5.23E-04
ILLRW	kg	1.41E-02	5.47E-05	2.20E-04	1.44E-02
CRU	kg	-	-	-	-
MFR	kg	3.51E+01	-	-	3.51E+01
MER	kg	-	-	-	-
EE	MJ	-	-	-	-

Table 4-3: Weighted average LCIA results for 1 metric ton of fabricated steel rebar

Parameter	Unit	Total	A1	A2	A3
GWP	kg CO ₂ eq.	8.54E+02	7.78E+02	4.90E+01	2.70E+01
ODP	kg CFC 11 eq.	1.09E-09	8.30E-10	8.38E-15	2.57E-10
AP	kg SO ₂ eq.	2.17E+00	1.58E+00	5.27E-01	6.10E-02
EP	kg N eq.	1.17E-01	7.87E-02	3.21E-02	6.11E-03
SFP	kg O ₃ eq.	4.91E+01	3.47E+01	1.30E+01	1.48E+00
ADP _{fossil}	MJ, surplus	1.02E+03	7.61E+02	9.18E+01	1.63E+02

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 calculated for each impact category. 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 fabricator.

Table 4-4: Statistical metrics of LCIA results for 1 metric ton of fabricated steel rebar across all facilities

Parameter	Unit	Min (A1-A3)	Max (A1-A3)	Max/Min Ratio (A1-A3)	Mean (A1-A3)	Median (A1-A3)
GWP	kg CO ₂ eq.	8.09E+02	1.00E+03	1.24E+00	8.46E+02	8.39E+02
ODP	kg CFC 11 eq.	8.24E-10	2.71E-09	3.29E+00	1.14E-09	1.01E-09
AP	kg SO ₂ eq.	2.06E+00	2.33E+00	1.13E+00	2.14E+00	2.13E+00
EP	kg N eq.	1.08E-01	1.27E-01	1.17E+00	1.14E-01	1.13E-01
SFP	kg O ₃ eq.	4.64E+01	5.41E+01	1.16E+00	4.84E+01	4.81E+01
ADP _{fossil}	MJ, surplus	8.41E+02	2.67E+03	3.18E+00	1.01E+03	8.73E+02

* ODP has limited relevance due to the absence of ozone-depleting emissions in the LCI, particularly in the foreground system. Use of region-specific electricity grid mix datasets for each fabricator therefore contributes to order of magnitude differences between ODP results for participating facilities.

4.1 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 majority of the potential environmental impacts is driven by the upstream burdens of steelmaking, therefore A1 is the dominant contributor across LCIA indicators.

Transportation between manufacturing and fabrication has a non-negligible impact on acidification, eutrophication and smog formation potential, up to a quarter of the impacts for fabricated rebar.

Figure 4-1: Impact assessment results for fabricated rebar

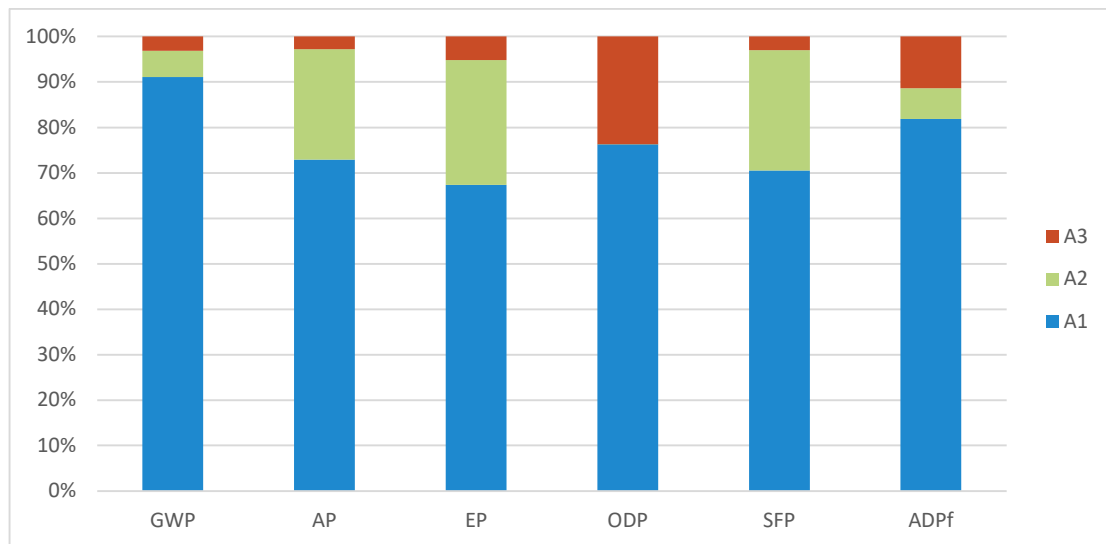
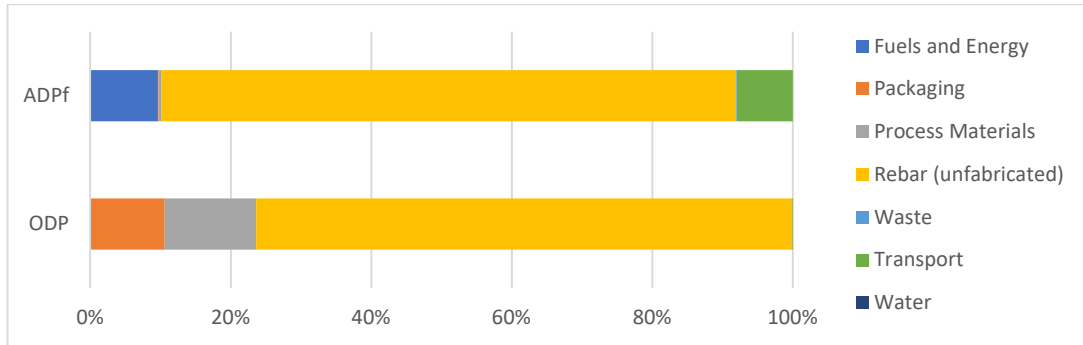


Figure 4-2: Impact breakdown - ADPf and ODP for fabricated rebar



As presented in Figure 4-2, fabrication doesn't represent more than 3% of cradle-to-gate impacts except for ODP and ADP_{fossil} . Most of the impact related to the fabrication stage (A3) is due to the fuels and energy used for ADP_{fossil} , while the impact of fabrication on ODP is due to process and packaging materials.

5 Interpretation

The interpretation is based on the assumptions and limitations described in this background report, both with regard to the methods and the data. A dominance analysis is used for interpretation.

5.1 Identification of Relevant Findings

Rebar production is categorized under module A1 and is the largest impact driver across all impact categories. This dominance of impact categories is primarily due to the alloying materials, electricity generation, and emissions from fuel combustion of the rebar manufacturing processes. Silico-manganese and vanadium, the two largest inputs (by mass) among the alloying materials, dominate the impacts for the alloying materials.

Inbound transportation (A2), the module in which steel rebar is transported to the fabrication facilities, is the second largest impact driver. Transport in A2 represents up to a quarter of cradle-to-gate impact for fabricated rebar (AP and EP and SFP from tailpipe emissions). Fabrication doesn't represent more than 3% of cradle-to-gate impacts except for ODP and ADP_{fossil}.

5.2 Assumptions and Limitations

Although the same Excel questionnaire was used for all participating fabricators, some fabricators returned more complete questionnaires than others. Fabricators that did not provide data that was complete enough were removed from the study.

The study did not model A1 according to the breakdown of rebar purchased by CRSI fabricators, but rather modelled A1 as a weighted average of rebar produced by CRSI members. Additionally, the distances used to calculate the production-weighted average distances in A2 reflect data provided in the questionnaires for rebar purchases at the fabrication facilities.

The fabrication data did not differentiate between fabrication of sections, plate, or non-structural steel products that are excluded from the scope of this assessment. Data were allocated to structural steel based on shop hours. The fabrication process is also assumed not to differ significantly between sections or plate.

Proxy data were applied to some materials where no matching life cycle inventories were available as documented in section 3.3.

Emissions of welding gases were calculated rather than measured in the absence of reported emissions data by the participating fabricators.

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. As seen in Table 4-4, variability of results is low, with the exception of ODP. 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 natural gas combustion emissions, 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 modelling 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 modelling approaches.

5.3.3 Representativeness

- ✓ **Temporal:** All primary data were collected for either 2019 or 2020. All secondary data come from the GaBi 2021 databases and are representative of the years 2017 to 2021, with the exception of upstream steel data which will be available in a future GaBi database release. 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 high.
- ✓ **Technological:** All primary and secondary data were modelled to be specific to the technologies or technology mixes under study. Where technology-specific data were unavailable, proxy data were used. 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 modelled 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 fabricated reinforcing steel in order to update the fabricated rebar EPD. This EPDs will allow CRSI's customers and professionals in the building and construction industry to make better-informed decisions about the potential environmental impacts associated with the products assessed in this study. Overall, the study found that environmental performance is driven primarily by steel production. Fabrication, which is driven mainly by energy consumption, accounts for less than 3% of global warming potential results for fabricated reinforcing steel.

5.5.2 Limitations

Data contributed to this report represents a fraction of CRSI's membership, with participating mill locations representing approximately 70% of total domestic rebar production – it is still reasonable to assume the results are representative of all members even if they did not contribute data because steel production is the predominant driver of impacts.

Furthermore, the study is limited to the environmental performance of fabricated reinforcing steel manufacturing and does not account for specific uses of these steel products.

5.5.3 Recommendations

In further future endeavors to mitigate environmental impacts, CRSI rebar manufacturers may want to explore opportunities to source electricity from low-impact alternatives. CRSI fabrication facilities may desire, as well, to source their electricity and fuels from more renewable sources. Additionally, fabricators may explore opportunities to source their rebar supply from nearby rebar manufacturers to reduce the A2 transportation burdens, keeping in mind the electricity and alloy sources of their suppliers.

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Annex A: Participating Companies

Mills		Fabricators	
Evrz	Pueblo, CO	Western States Rebar	Pleasant View, UT
CMC	Mesa, AZ	Rebarfab Inc.	New Brighton, MN
CMC	Jacksonville, FL	Katy Steel	Katy, TX
CMC	Sayreville, NJ	CMC	Dallas, TX
CMC	Durant, OK	CMC	Kissimmee, FL
CMC	Cayce, SC	CMC	Tracy, CA
CMC	Knoxville, TN	CMC	Auburn, WA
CMC	Seguin, TX	Nucor	Zellwood, FL
Cascade	McMinnville, OR	Nucor	New Braunfels, TX
Steel Dynamics	Roanoke, VA	Nucor	Kansas City, MO
Nucor	Auburn, NY	Dimension Fabricators	Scotia, NY
Nucor	Wallingford, CT	Farwest Steel	Vancouver, WA
Nucor	Flowood, MS	Farwest Steel	Eugene, OR
Nucor	Bourbonnais, IL	Re-Steel Supply Co	Eddystone, PA
Nucor	Kingman, AZ	Victory Steel Company (Re-Steel)	Baltimore, MD
Nucor	Marion, OH	Conco	Benicia, CA
Nucor	Jewett, TX	Conco	Rochester, WA
Nucor	Brigham City, UT		
Nucor	Birmingham, AL		

Annex B: Data Collection Periods

Mills	Data collection period
Company A	Calendar year 2019
Company B	Calendar year 2019
Company C	Calendar year 2019
Company D	Calendar year 2020
Company E	Calendar year 2020

Fabricators	Data collection period
Company A	September 1 st , 2019 – August 31 st , 2020
Company B	December 15 th , 2019 – December 19 th , 2020
Company C	Calendar year 2020
Company D	Calendar year 2020
Company E	December 1 st , 2019 – November 30 th , 2020
Company F	Calendar year 2020
Company G	Calendar year 2020
Company H	November 1 st , 2019 – October 31 st , 2020
Company I	Calendar year 2020
Company J	Calendar year 2020