

HOT ROLLED COIL/CHECKERED COIL

STRUCTURAL STEEL



TOKYO STEEL
MANUFACTURING CO., LTD.
started out as a small steel maker
in Tokyo almost 80 years ago. It
has since grown into Japan's
leading electric-arc-furnace
steelmaker with an annual
production of several million tons.

Tokyo Steel prides itself as a
recycler of steel scrap - its primary
raw material - letting it protect the
environment and thus contribute to
society. Recycling of steel products
with the electric arc furnace
process is truly the most effective
in terms of achieving a recycling-
based society and low-carbon
society at the same time. To
contribute to Japan's target of
reducing greenhouse gas (GHG)
emissions by 80% by 2050 while
making advanced use of steel
scrap that, in aggregate, amounts
to several decades' worth of
domestic steel demand, Tokyo
Steel will work, with strong
determination, to provide even
more diverse customers with a
wide range of products.



ENVIRONMENTAL PRODUCT DECLARATION



Hot Rolled Coil/Checkered Coil
Structural Steel

According to ISO 14025
ISO21930:2017

EPD PROGRAM AND PROGRAM OPERATOR NAME, ADDRESS, LOGO, AND WEBSITE	UL Solutions 333 Pfingsten Rd, Northbrook IL, 60062 www.ul.com www.spot.ul.com
GENERAL PROGRAM INSTRUCTIONS AND VERSION	Program Operator Rules v 2.7 2022
MANUFACTURER NAME AND ADDRESS	Tokyo Steel Manufacturing Co. Ltd. Kasumigaseki Tokyu Bldg. 15F 3-7-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-0013 Japan
DECLARATION NUMBER	4791119520.101.1
DECLARED PRODUCT & FUNCTIONAL UNIT OR DECLARED UNIT	Hot Rolled Coil/Checkered Coil Structural Steel, 1 metric ton
REFERENCE PCR AND VERSION NUMBER	Product Category Rules for Building-Related Products and Services, Part A: Life Cycle Assessment Calculation Rules and Report Requirements, UL Environment, Standard 10010, Version 4.0 Part B: Designated Steel Construction Product EPD Requirements Second Edition, Dated August 26, 2020)
DESCRIPTION OF PRODUCT APPLICATION/USE	Structural steel "Hot Rolled Coil/Checkered Coil" is mostly used in buildings and civil works, mainly in structural steel constructions. In addition to the construction sector there are numerous applications in very diverse sectors.
PRODUCT RSL DESCRIPTION (IF APPL.)	The Reference service life is not specified
MARKETS OF APPLICABILITY	Japan
DATE OF ISSUE	June 1, 2024
PERIOD OF VALIDITY	5 Years
EPD TYPE	Manufacturer Specific
EPD SCOPE	Cradle to gate
YEAR(S) OF REPORTED PRIMARY DATA	April 2022 and March 2023
LCA SOFTWARE & VERSION NUMBER	Microsoft Excel calculation tool with IDEA database
LCI DATABASE(S) & VERSION NUMBER	IDEAv3.1 database (2021)
LCIA METHODOLOGY & VERSION NUMBER	LIME2

The PCR review was conducted by

UL Solutions – PCR Review Panel – epd@ul.com

This declaration was independently verified in accordance with ISO 14025: 2006.

☐ INTERNAL ☐ EXTERNAL

Cooper McCollum, UL Solutions *Cooper McCollum*

This life cycle assessment was independently verified in accordance with ISO 14044
and the reference PCR by:

James Mellentine, Thrive ESG *James H. Mellentine*

LIMITATIONS

Exclusions: EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, environmental impact assessments, etc.

Accuracy of Results: EPDs regularly rely on estimations of impacts; the level of accuracy in estimation of effect differs for any particular product line and reported impact.

Comparability: comparison of the environmental performance of construction works and construction products using EPD information shall be based on the product's use and impacts at the construction works level. In general, EPDs may not be used for comparability purposes when not considered in a construction works context.

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Product information

Product description

The product declared is structural steel “Hot Rolled Coil / Checkered Coil”, which is classified as “Floor plates” in the Section 2, Classification of Material of the AISC 303 - 10 Code of Standard Practice for Steel Buildings and Bridges. The production process used is the Electric Arc Furnace. This route, used by TOKYO STEEL for the production of structural steel, is based on the direct melting of scrap with an Electric Arc Furnace, which is subsequently processed in rolling mills in order to obtain the finished products. The steel section is hot rolled into structural steel in coils. No metallic or organic coating.

The product is provided for Japan market and complies with JIS G 3101, JIS G 3106, JIS G 3136, JIS G 3113, JIS G 3125, JIS G 3132, JIS G 3131 (Regional designation code: JIS).



Application

Structural steel “Hot Rolled Coil / Checkered Coil” is mostly used in buildings and civil works, mainly in structural steel constructions. In addition to the construction sector there are numerous applications in very diverse sectors.

No specific product is needed to serve intended function in the construction work. Anticipated replacement cycle of product in the construction work will be about 20 years.

Technical data

Name	Value	Unit
Density	7,874	kg/m ³
Modulus of elasticity	2.1×10^5	N/mm ²
Coefficient of thermal expansion	11.7	$10^{-6}K^{-1}$
Thermal conductivity	48	W/(mK)
Melting point	1,516	°C
Electrical conductivity at 20C	1.0×10^7	$\Omega^{-1}m^{-1}$
Minimum yield strength	215	N/mm ²
Minimum tensile strength	315	N/mm ²
Minimum elongation	16	%
Tensile strength	436	N/mm ²
Compressive strength	235	N/mm ²
Grade of material according to the delivery standards	SS400	-

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Delivery status

The delivery conditions and dimension may vary according to the intended application.

Base materials / Ancillary materials

Structural steel “Hot Rolled Coil / Checkered Coil” is a low-alloy steel product. The typical content of carbon is lower than 0.18%. The share of other elements besides iron is typically around 1%. Steel scrap is a secondary raw material, defined in different qualities, depending on the composition (Fe content) and certain characteristics (plate, section steel, galvanized sheets, etc.).

The principal material is Steel and alloying elements are added on the form of ferroalloys and metals.

Any hazardous substances defined in Basel Convention and/or regulated by Japanese laws are not included in raw materials.

Manufacture

The steel scrap is melted in an electric arc furnace to obtain liquid steel, which is then refined in a ladle furnace with addition of ferroalloys and metals to obtain the required steel characteristics. The steel is then casted at a continuous caster to obtain semi-finished products. The semis are then rolled to the desired size.

TOKYO STEEL MFG produces the structural steel “Hot Rolled Coil / Checkered Coil” at one factory (Tahara factory).

Factory	Address
TOKYO STEEL MFG Tahara Plant	2-1-3, Shirahama, Tahara-shi, Aichi 441-3436, Japan



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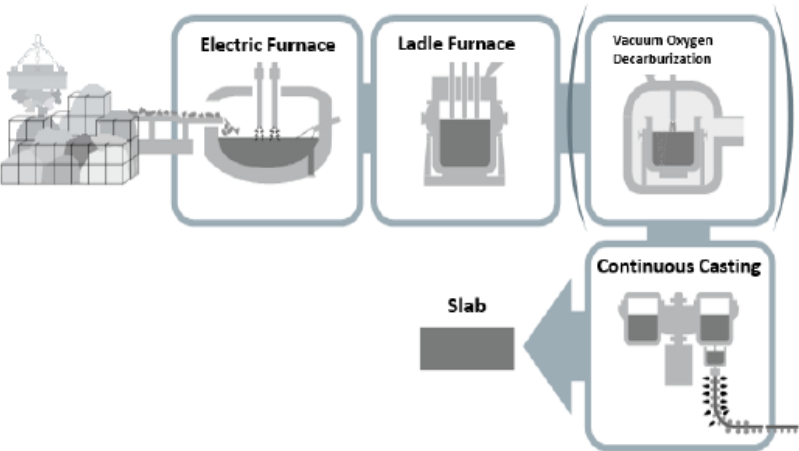
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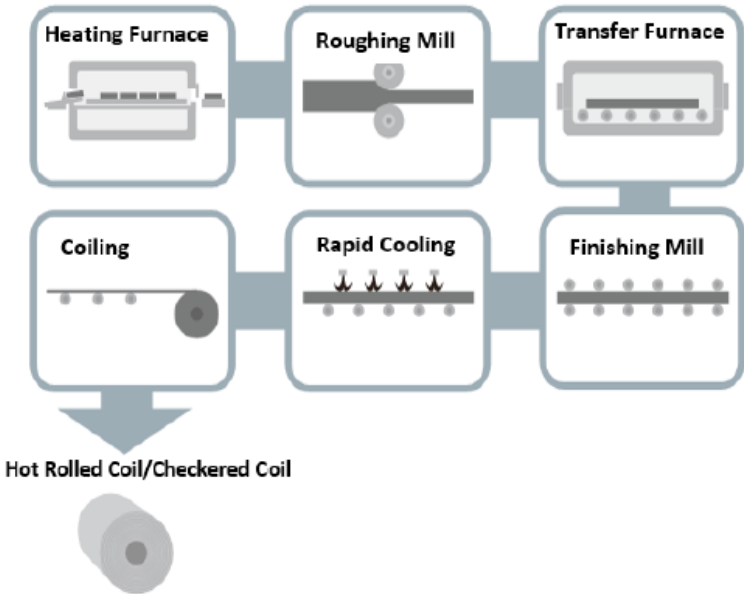
Manufacturing process flow

Manufacturing process flow

Steelmaking Process



Rolling Process



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Quality Management System

TOKYO STEEL MFG Tahara Plant is certified according to ISO9001 Quality Management System.

More information can be found at

<https://www.tokyosteel.co.jp/company/about/>

Environment and Health during manufacturing

TOKYO STEEL MFG Tahara Plant is certified according to ISO14001 Environment Management System.

More information can be found at

<https://www.tokyosteel.co.jp/company/about/>

Product processing/Installation

Processing and proper use of steel products depends on the application and should be made in accordance with generally accepted practices, standards and manufacturers recommendations. National technical regulations apply to the design and construction of steel structures. They deal with requirements for performance, sustainability, durability and fire resistance of steel and steel structures.

When handling and using the products, no additional means to protect health are required beyond the usual occupational safety measures.

No environmental impacts occur when working with or using these products under normal conditions of use. No special measures are necessary for the protection of the environment.

Residual materials are separated for in-house recycling. The steel scrap can be recycled almost completely.

Packaging

Structural steel "Hot Rolled Coil / Checkered Coil" is secured with strapping bands.

Condition of use

During use no changes in material composition shall occur. Maintenance requirement will depend on specific design and application.

Environment and health during use

Steel products, under normal conditions of use, do not cause adverse health effects.

If the steel products are used according to their intended use, under normal conditions, there will be no significant environmental impact to water, air/atmosphere and soil.



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Reference service life

The Reference service life is not specified. This LCA study covers only Module A1 to A3 and there are many different applications.

Extraordinary effect

Fire: Structural steels are classified as incombustible materials according to Notification No. 1400 by Ministry of Construction Japan

Water: Not relevant

Mechanical destruction: Not relevant

Re-use phase

Hot Rolled Coil / Checkered Coil can be reused after its recovery, in particular when steel constructions are properly designed to facilitate disassembly and re-use at the end of their useful lives.

Steel is 100% recyclable and scrap can be converted to the same (or higher or lower) quality of steel depending upon the metallurgy and processing of the recycling route.

Disposal

Due to its high value as a resource, steel scrap is not disposed of, but instead in a well-established cycle fed to reuse or recycling. Disposal is not included in the study.

The disposal pathway in Japan: Recycling (99%), Landfill (1%), Incineration (0%)

Waste code according to Basel convention is

A1010: Metal wastes

And Waste classification according to Japanese national law "Waste Management Law" is

Industrial Waste: 1210 Steel scrap

Industrial Waste shall be collected by a licensed collector.

Further information

Additional information can be obtained from <http://www.tokyosteel.co.jp/>

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LCA Rules

Declared unit

Name	Value	Unit
Declared unit	1	metric ton
Density	7,874	kg/m ³
Conversion factor to 1kg	0.001	-
Thickness	1.45 - 25.0	mm

System boundary

PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARYS
Raw material supply	Transport	Manufacturing	Transport from the gate to the site	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND

This is an EPD based on a cradle-to-gate life cycle assessment. The selected system boundaries of this study encompass the following steps and this LCA study is not comparative assertion.

A1: Production of raw materials and energy

A2: Transport of resources to the production site

A3: Production of the product

No known flows are deliberately excluded from this EPD except for strapping bands which were demonstrated to be below the cut-off threshold.

Capital goods and infrastructure flows are excluded from the product system boundary.

Estimates and Assumptions



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Regarding the transportation of materials, it is assumed:

- The distances of the transportation for 6% of Coal cokes were unknown. It was assumed that the distance of land transportation was 587.2km with truck and the distance of marine transportation was 450.0 km with ferry respectively.
- Internal circulation steel scraps were transported inside the plant from where they were produced to the Hot Rolled Coil / Checkered Coil production zone, and the distance of the transportation is assumed 2.9km.
- The truck size for transportation of coke, ferro-manganese and internal circulation steel scraps was unknown. Conservatively, a 10-ton truck was assumed.
- Average load rate in Japan was applied for all truck transportation.
- The bulk carrier size for marine transportation was unknown. Conservatively, less than 80k DWT of bulk carrier was assumed.
- The container ship size for marine transportation was unknown. Conservatively, less than 4k TEU container ship was assumed.

IDEA database provides the data from every electricity power company. Tokyo Steel is using the average power mix data from 10 major electric power companies in Japan.

Slag is recycled mainly for base layer of roads. Slag is considered as reminderflow in this study and the transportation for recycling is not considered in this study.

Cut-off rules

In the calculation of the A1 module, strapping bands were excluded after confirming the impact was small. They were 0.0359% of the total resources on a weight basis as input flows for the A1 module calculation.

The transportations of primary raw materials (Steel scrap, Coal coke, Calcium oxide, Ferro-manganese, and Internal circulation steel scrap) to the production site were included as input flows in the calculation of the A2 module. On the other hand, the transportations of the other raw materials were excluded as input flows in the calculation of the A2 module due to the lack of data availability, after confirming their impacts were small. The total excluded resources were 0.532% of the total resources on a weight basis as input flows for the A2 module calculation. The estimated energy usage and environmental impacts of the excluded input flows were explained in detail in the Interpretation section. These cut-offs met the criteria.

The cut-off criteria are 1 % of renewable primary resource (energy), 1 % nonrenewable primary resource (energy) usage, 1 % of the total mass input of that unit process and 1 % of environmental impacts. The total of neglected input flows per module are a maximum of 5 % of energy usage, mass and environmental impacts. These cut-off criteria align with ISO 21930.

Except the above cut-offs, all information from the data collection process has been considered, covering all used and registered materials, thermal energy, electrical energy, and diesel consumption.

Data quality

Principally the inventory data include material, energy, auxiliary, water consumption (foreground data). The foreground data are derived from Tahara Plant.

Further, LCA data sets (background data) linked to the foreground data of various stages of the life cycle (cradle to

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gate) were obtained from IDEAv3.1 database (2021).

Time coverage: Primary data was collected at Tahara Plant between April 2022 and March 2023. Secondary data comes from IDEAv3.1 database (2021). The data referenced year is 2015.

Geographical coverage: This product is produced and provided in Japan. Primary data was collected in Japan and secondary data was referred by Japan industry inventory from IDEA.

Technology coverage: State-of-the-art at the time when the data was developed.

Allocation

The manufacturing process generates by-products, slag, and internal circulation waste. All internal circulation waste outputs are input to this main product.

Most of energy as Electricity, Gas was measured at individual meter at each line. So there is no energy allocation except industrial water. Only industrial water volume was measured at a factory level so the industrial water volume was allocated based on the product manufacturing mass volume.

Comparability

Basically, a comparison or an evaluation of EPD data is only possible if all the data sets to be compared were created according to ISO 21930 and the building context, respectively the product-specific characteristics of performance, are taken into account.

Life Cycle Assessment Results

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

Environment Impact (Assessment Method: LIME2)					
Impact Category	Units	Total	A1	A2	A3
Global warming (GWP)	kg-CO ₂ eq	5.68E+02	1.53E+02	5.26E+00	4.11E+02
Acidification (AP)	kg-SO ₂ eq	4.51E-01	1.55E-01	1.03E-02	2.86E-01
Eutrophication (EP)	kgPO ₄ ³⁻ eq	2.31E-02	1.09E-02	2.60E-05	1.22E-02
Ozone depletion (ODP)	kg-CFC-11eq	2.79E-05	1.61E-05	6.55E-11	1.18E-05
Photo Chemical Ozone Creation (POCP)	kg-C ₂ H ₄ eq	1.34E-02	5.38E-03	6.26E-05	8.00E-03



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Comparability: Comparisons cannot be made between product-specific or industry average EPDs at the design stage of a project, before a building has been specified. Comparisons may be made between product-specific or industry average EPDs at the time of product purchase when product performance and specifications have been established and serve as a functional unit for comparison. Environmental impact results shall be converted to a functional unit basis before any comparison is attempted.

Any comparison of EPDs shall be subject to the requirements of ISO 21930. EPDs are not comparative assertions and are either not comparable or have limited comparability when they have different system boundaries, are based on different product category rules or are missing relevant environmental impacts. Such comparison can be inaccurate, and could lead to erroneous selection of materials or products which are higher-impact, at least in some impact categories.

Carbon dioxide emissions and removals from biogenic sources, carbonation, and combustion of waste are not relevant to this product system and were not included in the calculation of GWP.

Resource Use					
Parameter	Units	Total	A1	A2	A3
Renewable primary resources used as energy carrier	MJ	6.14E+02	2.94E+02	1.69E-03	3.20E+02
Renewable primary resources with energy content used as material	MJ	-	-	-	-
Non-renewable primary resources used as an energy carrier	MJ	8.20E+03	2.21E+03	8.82E+01	5.91E+03
Non-renewable primary resources with energy content used as material	MJ	-	-	-	-
Secondary materials	kg	1.11E+03	1.11E+03	-	-
Renewable secondary fuels	MJ	-	-	-	-
Non-renewable secondary fuels	MJ	-	-	-	-
Recovered energy	MJ	-	-	-	-
Use of net fresh water resources	m ³	6.14E+02	7.62E+01	1.80E-02	5.38E+02
Abiotic depletion potential for fossil resources	MJ	8.20E+03	2.21E+03	8.82E+01	5.91E+03

Output Flows and Waste Categories					
Parameter	Units	Total	A1	A2	A3
Hazardous waste disposed	kg	2.29E+00	8.82E-01	4.24E-08	1.41E+00
Nonhazardous waste disposed	kg	1.91E-10	1.90E-10	6.99E-17	2.89E-13
High-level radioactive waste, conditioned, to final repository (*)	kg	-	-	-	-
Intermediate- and low-level radioactive waste, conditioned, to final repository (*)	kg	-	-	-	-
Components for reuse	kg	-	-	-	-



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Materials for recycling	kg	1.58E+02	-	-	1.58E+02
Materials for energy recovery	kg	-	-	-	-
Recovered energy exported from the product system	MJ	-	-	-	-

(*) Radioactive waste data is not available in IDEA database.

Carbon Emissions					
Parameter	Units	Total	A1	A2	A3
Calcination Carbon Emissions	kg-CO ₂	1.79E+01	1.79E+01	-	-

Interpretation

Completeness

As mentioned before, strapping bands were excluded for the A1 module calculation, which were 0.0359% of the total included resources on a weight basis as input flows for the A1 module calculation.

The estimated environmental impacts of the excluded input flows accounts for 0.0096% for GWP, 0.0207% for ODP, 0.0169% for EP, 0.0123% for AP, and 0.0144% for POCP of the total, respectively.

Environment Impact (Assessment Method: LIME2)					
Impact Category	Units	A1-A3	A1	A1 impact of total	A1 impact
GWP	kg-CO ₂ eq	5.68E+02	1.53E+02	26.85%	0.0096%
AP	kg-SO ₂ eq	4.51E-01	1.55E-01	34.31%	0.0123%
EP	kgPO ₄ ³⁻ eq	2.31E-02	1.09E-02	47.01%	0.0169%
ODP	kg-CFC-11eq	2.79E-05	1.61E-05	57.61%	0.0207%
POCP	kg-C ₂ H ₄ eq	1.34E-02	5.38E-03	40.05%	0.0144%

The estimated energy usage of the excluded input flows accounts for 0.0172% of RPRE, 0.0097% of NRPRE of the total, respectively.

Environment Impact (Assessment Method: LIME2)					
Parameter	Units	A1-A3	A1	A1 impact of total	A1 impact
RPRE	MJ	6.14E+02	2.94E-03	47.85%	0.0172%

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NRPRE	MJ	8.20E+03	2.21E+03	26.92%	0.0097%
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The transportation of non-primary resources for the production, including strapping bands, were excluded from input flows for the A2 module calculation as explained in the cut-off rule. The total excluded resources were 0.532% of the total included resources on a weight basis as input flows for the A2 module calculation.

The estimated environmental impacts of the excluded input flows accounts for 0.0049% for GWP, 0.0000% for ODP, 0.0006% for EP, 0.0121% for AP, and 0.0025% for POCP of the total, respectively.

Environment Impact (Assessment Method: LIME2)					
Impact Category	Units	A1-A3	A2	A2 impact of total	A2 impact
GWP	kg-CO ₂ eq	5.68E+02	5.26E+00	0.92%	0.0049%
AP	kg-SO ₂ eq	4.51E-01	1.03E-02	2.28%	0.0121%
EP	kgPO ₄ ³⁻ eq	2.31E-02	2.60E-05	0.11%	0.0006%
ODP	kg-CFC-11eq	2.79E-05	6.55E-11	0.00%	0.0000%
POCP	kg-C ₂ H ₄ eq	1.34E-02	6.26E-05	0.47%	0.0025%

The estimated energy usage of the excluded input flows accounts for 0.0000% of RPRE, 0.0057% of NRPRE of the total, respectively.

Environment Impact (Assessment Method: LIME2)					
Parameter	Units	A1-A3	A2	A2 impact of total	A2 impact
RPRE	MJ	6.14E+02	1.69E-03	0.0003%	0.0000%
NRPRE	MJ	8.20E+03	8.82E+01	1.07%	0.0057%

Sensitivity

Proxies of emission factors were used for a few materials and activities because precise emission factors for them were not available in IDEA v3.1 database.

Environment Impact (Assessment Method: LIME2)				
Impact Category	Units	A1-A3	Impact of proxies	10% of proxies impact
GWP	kg-CO ₂ eq	5.68E+02	0.37%	0.04%



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AP	kg-SO ₂ eq	4.51E-01	10.72%	1.07%
EP	kgPO ₄ ³⁻ eq	2.31E-02	18.87%	1.89%
ODP	kg-CFC-11eq	2.79E-05	0.69%	0.07%
POCP	kg-C ₂ H ₄ eq	1.34E-02	1.31%	0.13%

Steel scrap processing impacts are based on an environmentally extended economic input/output (EEIO) data set using the amount spent on scrap as the quantity. Since EEIO data sets are generally considered to have lower accuracy compared to data sets based on physical flows, the EEIO data impact has been evaluated as below.

Environment Impact (Assessment Method: LIME2)						
Impact Category	Units	A1-A3	A1	EEIO data	EEIO data in A1	EEIO data in total
GWP	kg-CO ₂ eq	5.68E+02	1.53E+02	4.89E+01	32%	9%
AP	kg-SO ₂ eq	4.51E-01	1.55E-01	3.83E-02	25%	8%
EP	kgPO ₄ ³⁻ eq	2.30E-02	1.09E-02	1.57E-03	14%	7%
ODP	kg-CFC-11eq	2.79E-05	1.61E-05	9.48E-06	59%	34%
POCP	kg-C ₂ H ₄ eq	1.34E-02	5.38E-03	4.86E-04	9%	4%

Consistency

All manufacturing data was gathered with the same level of detail and all background data were sourced from IDEA database selecting most appropriate geography.

Representativeness

Tahara Plant produces Structural steel "Hot Rolled Coil / Checkered Coil". The foreground data from Tahara Plant was used.

Limitation

LIME characteristic methodology and IDEA database are used in the study. These are specific to Japan market so these are considered as limitations when the data will be used in other countries.

And some data are not available in IDEA database. Radioactive waste data for nuclear power plant electricity is not covered.

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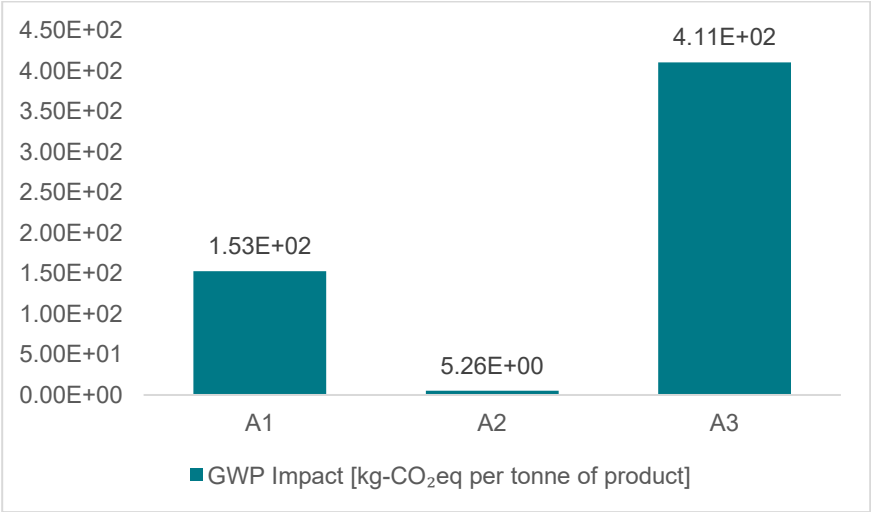


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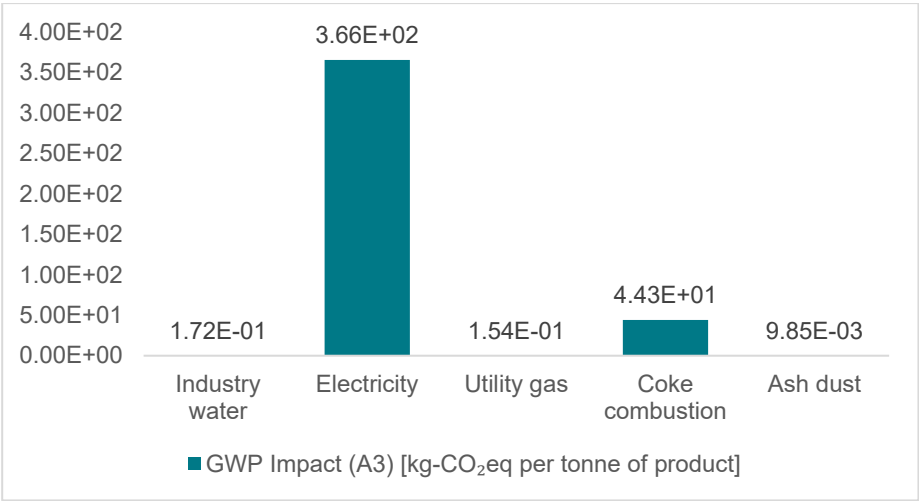
According to ISO 14025

Conclusion

Tokyo steel uses the Electric Arc Furnace production process to utilize steel scrap. This process can save material impact instead use more energy. A3 is the biggest portion in GWP.



And in A3, Electricity impact is the biggest item. So the electricity usage will be a challenge to reduce the environmental impact.



References



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According to ISO 14025

DIN EN /ISO 14025:201110: Environmental labels and declarations - Type III environmental declarations - Principles and procedures

ISO 14040:2006 - Environmental management – Life cycle assessment – Principles and framework

ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines

ISO 21930:2017 - Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services

ISO 14001:2015 - Environmental management systems -- Requirements with guidance for use

ISO 9001:2015 - Quality management systems – Requirements

JIS G 3101: Rolled steels for general structure

JIG G 3106: Rolled steels for welded structure

JIG G 3136: Rolled steels for building structure

JIG G 3113: Hot-rolled steel plates, sheet and strip for automobile structural uses

JIG G 3125: Superior atmospheric corrosion resisting rolled steels

JIG G 3132: Hot-rolled carbon steel strip for pipes and tubes

JIG G 3131: Hot-rolled mild steel plates, sheet and strip

Notification No. 1400 by Ministry of Construction Japan: Classification of incombustible materials

Product Category Rules for Building-Related Products and Services, Part A: Life Cycle Assessment Calculation Rules and Report Requirements, UL Environment, Standard 10010, Version 4.0

Part B: Designated Steel Construction Product EPD Requirements Second Edition, Dated August 26, 2020

Environment



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Secondary dataset

IDEAv3.1 database (2021).

National Institute of Advanced Industrial Science and Technology

Japan Environmental Management Association for Industry

National Greenhouse Gas Inventory Report of Japan 2022, Ministry of the Environment, Japan, Greenhouse Gas Inventory Office of Japan, Center for Global Environmental Research, National Institute for Environmental Studies, Japan

