# Steel Emissions Reporting Guidance

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August 2022

In collaboration with the World Business Council for Sustainable Development (WBCSD) and its Automotive Partnership for Carbon Transparency (A-PACT) initiative
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# 1 BACKGROUND

## 1.1 Introduction

Steel is critical to the functioning of modern society. It is not only used ubiquitously in buildings, transport, infrastructure, and machinery but is also fundamental to the development of key technologies required by the energy transition, such as wind turbines.

The steel sector is also a major source of greenhouse gas (GHG) emissions.[1] Steel production is directly responsible for ~2.6 Gt $CO_2$ emissions in 2020, which is ~7 percent of the global emissions, in addition to ~1.0 Gt $CO_2$ from electricity use by the sector. Current production methods rely on fossil fuel for energy and oxygen removal from iron minerals. As a result, fundamental changes to production methods are required to decarbonize the sector.

Due in part to its widespread use, there is significant demand for steel produced with low emissions from end-users concerned with climate mitigation, such as wind turbine and electric vehicle manufacturers. To satisfy this demand, it is necessary for actors in the steel supply chain to provide transparent and comparable information on emissions. This will allow purchasers to confidently procure steel with low embodied emissions and ensure these purchasing decisions drive decarbonization in the steel sector.

This guidance provides the details on emissions calculation and reporting, which steel companies can use to satisfy those requirements and, thus, meet the demand for low embodied emissions steel.

## 1.2 Purpose

The purpose of this guidance is to provide a tool for steel companies to report emissions in a way that enables the development of a differentiated market for low embodied emissions steel that promotes the necessary investments to decarbonize the sector.

[1] Throughout this guidance, "emissions" is used as shorthand for all greenhouse gas emissions (measured as $CO_2$ equivalent).

The broad outcome of the implementation of this tool is as follows:

1. Accelerate the deployment of low-emissions steel production technologies by ensuring sufficient information is available to link demand with supply.
2. Increase transparency on steel production emissions with a methodology that is consistent across geographies and commodities.
3. Enable steel consumers to purchase with a clear embodied emissions association and demonstrate evidence of that emissions performance to their customers.
4. Credibly recognize steel producers leading their peers in terms of emissions performance, particularly in the deployment of new technologies.

## 1.3 Principles

This guidance is developed based on the broad carbon accounting principles of RMI's Horizon Zero project. The overarching principle is the need to report emissions at the product level from a specific asset. This is required because the product is the basis for purchasing decisions, which this guidance seeks to inform.

To enable useful product-level emissions disclosures, the Steel Emissions Reporting Guidance uses three key principles:

1. Use primary data – As much as possible, emissions calculations should be based on first-hand information from actors in the supply chain.
2. Create a boundary for comparison – Companies should report emissions against a fixed boundary (i.e., a consistent set of processes) to enable comparability between disclosures.
3. Measurement made for markets – Ensure calculation and reporting decisions provide the transparency necessary to enable the development of a market for low embodied emissions products.

This guidance provides the details specific to the steel sector to implement these broad accounting principles.

# 2 EMISSIONS REPORTING REQUIREMENTS

There are four key requirements for reporting steel sector emissions using this Steel Emissions Reporting Guidance:

1. Product level – Emissions must be reported at the product level for an individual site.
2. Fixed boundary – All emissions from a set of processes must be reported irrespective of whether the company has ownership or control of these processes.
3. Supply chain transparency – Additional context on emissions with regard to the ore or scrap metallic inputs used to assist in understanding the overall emissions footprint.
4. Data source – Emissions disclosures must include the fraction of the emissions footprint that is based on primary data (refer to section 3.5)[20] and separately report any emissions credits.

Using these key requirements, the data reported for each product is as follows:

- The overall emissions footprint (emissions per unit mass) for the steel product (refer to Section 3.1).
- The fraction of scrap-based inputs used to generate the product (refer to Section 3.2).
- Additional information on emissions incurred during the processing of the ore-based and scrap-based inputs used in the product (refer to Section 3.3).
- The fraction of primary data used to calculate the overall emissions footprint (refer to Section 3.6).
- The emissions footprint of any claim credits separate to the overall footprint (refer to Section 3.5).

These data provide steel purchasers with a technology agnostic set of information required to understand and value emissions reductions made by steelmakers across the key changes required to decarbonize the sector.

## 2.1 Product Level

A core component of the Steel Emissions Reporting Guidance is the reporting of emissions intensity on the product level from individual sites/supply chains. The aim of such reporting is to enable the emissions information to flow alongside the product. This allows the emissions information to accumulate as products are moved (and transformed) along a supply chain, thereby enabling each actor in the chain to accurately understand the embodied emissions of purchased and sold products.

To achieve this, companies should report the emissions intensity of steel produced at each asset. If parallel independent lines of steelmaking exist at a single asset, companies may separately report the emissions intensity of steel produced from each line. This is intended to ensure that when an operating line uses a substantially different, low-emissions technology, companies are able to demonstrate the low emissions performance of products from that line.

The emissions intensity calculations should be based on Section 3 and in line with the other reporting requirements outlined in this section.

## 2.2 Fixed System Boundary

The fixed system boundary defines all the process steps from which emissions need to be reported irrespective of the steel companies' ownership structure. This approach solves two key issues:

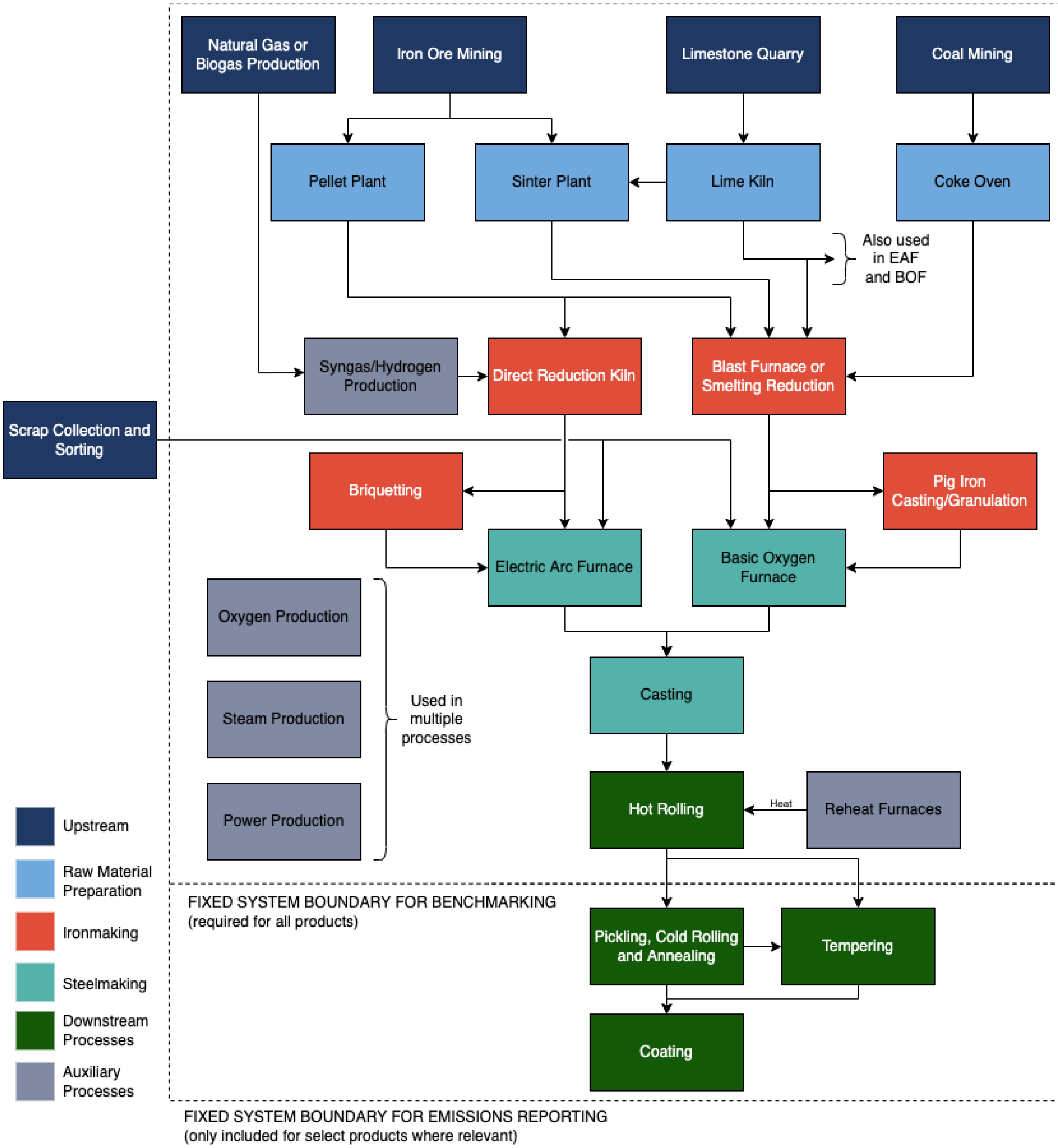
1. **Emissions disclosure at the corporate level will vary depending on the degree of vertical integration**. In some instances, vertical integration can extend to emissions-intensive upstream processes such as sintering and coke production. If these processes are operated (and owned) by a steelmaker, emissions will be included in scope 1 (according to the GHG Protocol). For non-integrated operators, the same emissions would count as scope 3, which may not be reported, presenting challenges to comparing GHG emissions across the sector.
2. **Scope 1, 2, and 3 will likely become more fluid overtime, further limiting comparability.** For example, as the use of direct reduced iron (DRI) increases to enable a shift to hydrogen-based steelmaking, emissions may be included as scope 1 (for DRI using on-site produced green hydrogen), scope 2 (where purchased electricity is used to make hydrogen), or scope 3 (for DRI produced by a third party).

Exhibit 1 shows the fixed system boundary required for reporting, which is similar to the existing practices for various emissions accounting purposes in the steel sector (refer to Appendix). To enable comparison between products, a benchmarking point (after hot rolling) is defined — all products will require emissions reporting to this point.

If the steel product also requires further processing (e.g., galvanized sheet, cold rolled coil, etc.), emissions from the processes between the benchmarking point and the final product should be separately reported.

This guidance includes the hot rolling process into the benchmarking boundary to enable more comparability between steel products. More than 95 percent of steel is hot rolled,[12] and as a large consumer of fuel for heat, its inclusion simplifies the emissions reporting for integrated operations.

## Exhibit 1: Fixed System Boundary for Steel Sector Emissions Reporting




Source: RMI

## 2.3 Ore-based and Scrap-based Inputs

Steel is produced using ore-based (mined) and scrap-based (recycled) metallic inputs. Production from ore-based inputs is inherently more energy-intensive as oxygen has to be removed (reduction) from iron minerals. Current ore-based processing routes largely use coal as the main energy source, implying >90 percent of the sector's direct emissions is associated with steel production from ore.[8]

Today, around one-third of the steel is produced from scrap-based inputs.[18] However, the supply of scrap steel is dependent on the availability of steel containing products nearing expiration. In the last quarter century, as urban centers were built in China and elsewhere, a huge amount of iron ore was converted to steel, most of which (a potential source of secondary inputs) is still in existing infrastructure. The latest available modeling, including from the IEA[8] and Mission Possible Partnership[19], maintains there is not sufficient scrap to meet the entire demand for steel to 2050. For example, under the IEA Net Zero Emissions (NZE) scenario, only around half of the steel demand can be met by scrap in 2050.[18] Due to this constrained supply, it is impossible to completely decarbonize the steel sector by switching to steel produced from secondary sources. It will also be necessary to deploy new zero emissions ore-based steelmaking technologies.

To overcome this challenge, steelmakers should disclose the fraction of ore and scrap inputs used to produce steel (refer to Section 3.1). Further context on emissions in relation to the inputs used is also necessary due to the dynamics of scrap supply outlined above. The sliding-scale (based on scrap input) grading system proposed by ResponsibleSteel provides some context. In addition, further granularity can be provided by reporting the emissions during the processing of the ore and scrap inputs separately (as supplemental information to total emissions intensity). This enables purchasers of steel that rely mostly on ore-based steel (e.g., automakers due to material specification requirements) to understand and accurately assess the emissions intensity of alternative suppliers. This approach also allows steelmakers to demonstrate emissions reductions from technology deployments (which often have a higher cost of abatement) independently from the fraction of scrap-based inputs used or reduction in emissions to melt scrap (which is mostly electrified and typically cheaper to decarbonize). The procedures for calculating this supplemental information are provided in Section 3.3.

Often, the differentiation between ore-based and scrap-based steel is based on the processing technology route (such as in the EU ETS).[4] However, most steelmaking technologies utilize a mix of inputs limiting the effectiveness of this method in isolation. As a result, any information on the technology used would need to be additional to the emissions intensity and scrap fraction and provide more granularity on the type of technology (e.g., further breakdown of direct reduction into natural-gas or green-hydrogen based). Use of the additional metrics outlined in Section 3.3 allows the reporting to remain consistent as steelmaking technology evolves.

## 2.4 Data Sources

To ensure emissions performance-based decisions drive investments in low-emissions technologies, it is necessary to use primary data, i.e., data provided directly from the entity responsible for those emissions (i.e., scope 1 or 2 of these entities).

Steel companies should report the fraction of emissions calculated using primary data. This may require companies to also request the fraction of primary data used in emissions estimates from upstream suppliers or downstream customers. The definition of primary data and the methodology for companies to calculate the fraction of primary data are provided in Section 3.6.4.

# 3 EMISSIONS CALCULATIONS REQUIREMENTS

## 3.1 Emissions Calculation Procedure

The calculation procedure is based on the ISO 14404 series, specifically

$$E_{CO2} = \sum_{t=1}^{N} K_{t,d,CO2} \times Q_{t,d,CO2} + \sum_{t=1}^{N} K_{t,i,CO2} \times Q_{t,i,CO2} - \sum_{t=1}^{N} K_{t,e,CO2} \times Q_{t,e,CO2}$$

where *t* (from 1 through N) refers to each emissions source (i.e., fuel, energy, or other input); *K* refers to emissions factors; *Q* refers to site quantity; and *d*, *i*, and *e* refer to direct, indirect, and export emissions, respectively.[9]

This calculation provides the overall emissions converted to an intensity by dividing by the mass of steel produced.

These categories of emissions are defined as follows:

- Direct – Refers to emissions from fuel sources, electricity use, and other inputs, where the emissions factor is defined based on the carbon content of that fuel source/electricity generation/input.

- Indirect – Refers to emissions that occur outside of the steel plant (e.g., if pellets are imported) but need to be reported as part of the fixed system boundary (refer to Section 2.2). These emissions should be determined by the relevant producer/consumer and transferred to the reporting entity. If this is impossible, average emissions factors can be used but these will impact the fraction of primary data — which is designed to highlight that the use of these factors weakens the reliability of the data and can possibly lead to overestimation emissions for efficient facilities and processes (refer to Section 3.6.4).

- Export – Refers to emissions that should be subtracted from the emissions estimate because these were incurred to generate an exported product other than steel. This only applies to emissions allocated to intermediate products (pellets, DRI, etc.) that are sold. It does not include the emissions impact outside the plant calculated by system expansion, such as those for blast furnace slag sold to produce concrete. Refer to Section 3.5 for details.

The required emissions sources and associated emission factors for direct and upstream are provided in Section 3.6.

## 3.2 Share of Metallic Inputs

The metallic input to produce steel can either be sourced from iron ore or scrap. Scrap is typically sourced as either of the following:

- Pre-consumer scrap – Material diverted as a waste stream during manufacturing (e.g., off-cuts from a stamping process). Pre-consumer scrap is further categorized as follows:
  - Home scrap - Generated at the same site that produces steel.
  - Fabrication scrap - Produced outside of the steel plant by downstream manufacturing processes.
- Post-consumer scrap – Recovered from steel containing products nearing expiration (e.g., recycling of steel from end-of-life cars).

The biggest environmental benefit is derived from the use of post-consumer scrap to displace the production of steel from iron ore. However, defining the share of metallic inputs based on the use of post-consumer scrap may be challenging as post- and pre-consumer scrap may be mixed in collection and sorting.

The share of metallic inputs used at a given steel production site is required to provide purchasers with information on the fraction of recycled content used and utilized as an input to calculations to determine emissions incurred in the processing of ore-based and scrap-based inputs.

To simplify the calculation, any purchased external scrap (fabrication or post-consumer) is considered a scrap-based metallic input. Scrap sold by the site is to be subtracted from the purchased external scrap to ensure home scrap is not counted. The primary inputs are based on the mass and iron content of purchased ore-based metallic inputs (i.e., iron ore, pellets, sinter, pig iron and DRI/Hot Briquetted Iron). As such, the calculation for the fraction of scrap-based inputs is

$$F_s = \frac{M_s}{\left(M_S + \sum_{i=1}^{N} M_p \times x_p\right)}$$

where $M_s$ is the mass of scrap (defined as the mass of purchased external scrap minus the mass of sold home scrap), and $M_p$ and $x_p$ are the mass and iron grade of each primary input used, respectively.

Depending on the level of vertical integration at a steelmaking site, scrap from different processes can be classified as either home or fabrication scrap. As a result, it is recommended that steelmakers provide additional information on the amount of home scrap generated (per unit of steel output) so that purchasers can understand these discrepancies.

## 3.3 Supplemental Reporting of Ore-Based and Scrap-Based Emissions Intensity

This calculation is designed to provide additional information on the steel product besides the total emissions intensity, specifically that from processing the ore and scrap inputs used to generate the product. This provides additional transparency on the supply chain of the steel product, which enables purchasers to ensure procurement decisions are directed toward products that have the most impact on decarbonizing the sector.

Using this approach, the emissions during the processing of each input are determined (up to the benchmarking boundary shown in Exhibit 1), allowing steelmakers to independently demonstrate emissions reductions in the processing of each input. This would enable a purchaser to tailor a procurement strategy to maximize sector-wide decarbonization (e.g., by focusing on steel with low emissions from processing ore inputs, given that currently >90 percent of the sector's emissions come from these processes) while being agnostic on the deployed decarbonization technology.

To calculate the emissions from processing each input, the benchmarking system boundary is divided into two more boundaries:

1. Ironmaking – Includes all the processes in the upstream, raw material preparation, and ironmaking categories listed in Exhibit 1.
2. Steelmaking – Includes all other processes in the steelmaking and downstream processing categories up to the benchmarking boundary listed in Exhibit 1.

For each of these two system boundaries, the total emissions are determined based on all energy and other inputs to the processes within the boundary (as per Section 3.1). All emissions from the ironmaking system boundary are associated with the treatment of ore-based inputs (as scrap is introduced downstream), while the emissions from the steelmaking boundary are divided according to the mass share of metallic inputs. Note that upstream emissions associated with ferroalloy production are allocated based on the mass fraction irrespective of where in the process these inputs are used, as the alloying elements provide a direct function to the final product.

Note previous discussions did not reach consensus on this topic, please refer to the survey questions

An example of the calculation method using these boundaries is provided in Exhibit 2.

## Exhibit 2: Process Level Calculation Example

| PARAMETER | | ORE-BASED | SCRAP-BASED |
|---|---|---|---|
| Annual emissions (Mt $CO_2$)[2] | Ironmaking | 5.0 | |
| | Steelmaking | 0.5 | |
| Metallics input fraction (%) | Ironmaking | 100% | 0% |
| | Steelmaking | 80% | 20% |
| Emissions to treat inputs for each process (Mt $CO_2$) | Ironmaking | 5.0 = (5.0 * 100%) | 0.0 = (5.0 * 0%) |
| | Steelmaking | 0.4 = (0.5 * 80%) | 0.1 = (0.5 * 20%) |
| Total emissions (Mt $CO_2$) | | 5.4 = (5.0 + 0.4) | 0.1 = (0.0 + 0.1) |
| Total annual steel production (Mt) | | 3.0 | |
| Steel production from each input (Mt) | | 2.4 = (3.0 * 80%) | 0.6 = (3.0 * 20%) |
| Emissions intensity (t $CO_2$/t) | | 2.25 = (5.4 / 2.4) | 0.16 = (0.1 / 0.6) |

## 3.4 Exported Products

Emissions incurred to produce exported intermediate products that can be used within the steel supply chain can be subtracted from the overall emissions footprint, as outlined in Section 3.1. This is designed to ensure the reported emissions are focused only on those that are required to produce steel at a site. Only the emissions that occur within the fixed system boundary (refer to Section 2.2) and can be allocated using a physical relationship to an exported product may be subtracted. Emissions calculated via system expansion (as opposed to allocation) are considered credits and reported separately to the overall emissions footprint (refer to Section 3.5).

For example, if a site operates a pellet plant that also exports some pellets, these can be subtracted from the total emissions footprint. This ensures only the emissions from pellets consumed in the steelmaking on-site are included. The emissions of the exported pellets would instead be included in the emissions calculation of the steel producer that purchases those pellets.

Steelmakers should determine the actual emissions intensity from the manufacture of intermediate products to be deducted from the total emissions footprint. This involves determining the emissions associated with all processes within the fixed boundary, which are required to produce the intermediate product (e.g., for pellets, this would be iron ore mining and pelletization). The emissions intensity is then determined by the sum of emissions from the selected processes divided by the total volume of the intermediate product. An example of this calculation is provided in Exhibit 3.

[2] Although we mention GHG emissions as Mt $CO_2$, we recommend that emissions calculations include all GHGs ($CH_4$, $N_2O$, and others)

## Exhibit 3: Example Calculation for Intermediate Product Credits

| PARAMETER | VALUE |
|---|---|
| Total pellet production (Mt) | 4.0 |
| Total emissions to produce pellets (Mt $CO_2$) | 0.5 |
| Pellet emissions intensity (t $CO_2$/t pellets) | 0.125 = (0.5 / 4.0) |
| Pellets exported (Mt) | 1.0 |
| Total site emissions (Mt $CO_2$) | 5.625 |
| Exported pellets emissions subtraction (Mt $CO_2$) | 0.125 = (0.125 * 1.0) |
| Total site emissions (Mt $CO_2$) after subtraction | 5.5 |

If a site does not have the sufficient granularity to calculate the emissions intensity of an exported product, the default emissions factors in Exhibit 4 can be used. If these factors are used in the emissions calculations, this will reduce the fraction of primary data (refer to Section 3.5.4)

## Exhibit 4: Default Credit Emissions Factors

| $CO_2$ EMISSIONS SOURCE | UNIT | EMISSIONS FACTOR ($tCO_2$/UNIT) | SOURCE |
|---|---|---|---|
| Coke | t | 3.481 | WSA, 2021[3] |
| Pellets | t | 0.137 | WSA, 2021 |
| Sinter | t | 0.262 | WSA, 2021 |
| Hot metal/pig iron | t | 2.027 | WSA, 2021 |
| Gas-based DRI | t | 0.853 | WSA, 2021 |
| Coal-based DRI | t | 1.283 | WSA, 2021 |

## 3.5 Credits

Credits are defined as avoided emissions outside of the fixed system boundary, which occur due to the use of by-products from the steelmaking facility. To account for the avoided emissions, credits are calculated using the system expansion methodology. The total credit is required to be separately reported from the total emissions intensity.

### 3.5.1 By-products used in Other Supply Chains

Steel plants can produce several by-products such as ground granulated blast furnace slag (GGBFS) and coal tar, which can be used in the supply chains for other products. For example, GGBFS can be used as a cement substitute in concrete to lower the embodied emissions of that product.

These by-products are typically treated as having zero emissions burden by the consuming sector (e.g., GGBFS is assumed to have zero embodied emissions by concrete manufacturers). As a result, the consuming sector is incentivized to use this by-product as an input to lower emissions. To maintain consistency with this accounting practice, no credit is applied to the steel product emissions footprint for producing the by-product (as this would require the consuming sector to assume a non-zero emissions burden for the by-product to maintain the overall emissions accounting). This approach is consistent with the latest standards development in the steel sector (see Appendix).

Emissions associated with processes to upgrade by-products (i.e., processes not included in the fixed system boundary shown in Exhibit 1) do not need to be included in the steel emissions calculation. For example, emissions associated with blast furnace slag granulation and grinding do not need to be included in the steel product emissions footprint. Steel producers are encouraged to provide data on emissions from these processes to by-product purchasers.

### 3.5.2 Energy Exports

Some steelmaking operations, particularly coke-making and blast furnace, produce off-gases containing hydrogen, carbon monoxide, and carbon dioxide, which can be combusted to produce heat or electricity. In most integrated facilities, these off-gases are used to provide energy inputs to other parts of the process (e.g., pre-heating coal fed into coke ovens).

Many steel production facilities will also use these off-gases to produce electricity via a facility on-site owned by the steelmaker or by exporting these to a nearby third-party power producer and purchasing electricity back from the third party. In some cases, the steel production site may be a net-exporter of electricity (using either of the above ownership mechanisms).

The emissions intensity of electricity generated from steel plant off-gases is dependent on the mix of gases. For example, coke oven gas is less carbon-intensive (44 kg $CO_2$/GJ) compared with blast furnace gas (260 kg $CO_2$/GJ). For a typical mix (e.g., 60 percent blast furnace and 40 percent coke oven gas) and conversion efficiency (37 percent), the resulting electricity generation emissions intensity is ~1.7 t $CO_2$/MWh. This is ~3x higher than the global grid (0.438 t$CO_2$/MWh) emissions intensity and higher than production from a coal-fired power plant (~1 t$CO_2$/MWh).[21]

Steelmakers typically re-use off-gases within the process to the maximum extent possible (e.g., for heat/reduction). If this is impossible, the emissions associated with the net-exported electricity should be assessed using the formula below.

$$E = V_e \times (EF_{off-gas} - EF_{displaced})$$

where $E$ is the emissions from net-export of electricity, $Ve$ is the volume of exported electricity (MWh), $EF_{off\text{-}gas}$ is the emissions factor to produce electricity from the off-gases (t$CO_2$e/MWh), and $EF_{displaced}$ is the emissions factor of electricity displaced by the steelmaker's export.

The calculation procedure for the volume and off-gas emissions factor is provided in Section 3.6.2. For the displaced electricity factor, a tiered approach is used:

1. Consequential emissions – Based on a consequential lifecycle study (i.e., inclusive of market-mediated effects) to determine the electricity source (and its associated emissions) that would replace the steelmaker's exports if these exports were to be stopped.
2. Country/regional grid average – Where consequential data are unavailable, the average grid emissions (e.g., using IEA data) for the country or region can be used.
3. Global grid average – Where the above data sources are unavailable, the global grid average emissions from the IEA can be used.

Note previous discussions did not reach consensus on this topic, please refer to the survey questions

## 3.6 Data Sources

### 3.6.1 Direct Emissions Factors

Direct emissions sources refer to fuel (solid, liquid, or gas) used on-site in the production of steel. Where possible, steelmakers should determine the carbon content of the specific fuel used on-site to determine a site-specific emissions factor (assuming complete conversion of the contained carbon to carbon dioxide). If this is impossible, the standard emissions factors for various fuel types provided in Exhibits 5 and 6 can be used.

## Exhibit 5: Emissions Factors for Solid Fuel Sources

| $CO_2$ EMISSIONS SOURCE | UNIT | EMISSIONS FACTOR ($tCO_2$/UNIT) | SOURCE |
|---|---|---|---|
| Coking coal | t | 3.06 | WSA, 2021[3] |
| Ironmaking coal[3] | t | 2.953 | WSA, 2021 |
| Sinter/BOF coal | t | 2.785 | WSA, 2021 |
| Steam coal | t | 2.462 | WSA, 2021 |
| Charcoal | t | 3.477 | IPCC, 2006 |
| Petroleum coke | t | 3.177 | IPCC, 2006[1] |
| EAF coal | t | 3.257 | WSA, 2021 |

## Exhibit 6: Emissions Factors for Liquid and Gas Fuel Sources

| $CO_2$ EMISSIONS SOURCE | UNIT | EMISSIONS FACTOR ($tCO_2$/UNIT) | SOURCE |
|---|---|---|---|
| Light oil | $m^3$ | 2.601 | WSA, 2021[3] |
| Heavy oil | $m^3$ | 2.907 | WSA, 2021 |
| Diesel | t | 3.197 | IPCC, 2006[1] |
| LPG | t | 2.985 | WSA, 2021 |
| Natural gas | t | 2.695 | IPCC, 2006 |

These emissions factors refer to the emissions associated with the conversion of the carbon content of each fuel to carbon dioxide. The production process for each fuel also involves emissions, most notably, fugitive methane emissions, particularly in coal and natural gas production. Given that fuel production processes are covered in the fixed boundary, these emissions must also be reported. If possible, the fuel provider should determine the methane emissions and provide this information to the steelmaker. There are several methodologies for determining fugitive methane emissions, and the fuel producer should use an existing standard (such as the MiQ standard for natural gas or the EPA methodology for coal) to determine methane emissions.[15,16] If this is impossible, the steel producer may use the standard emissions factor provided in Section 3.6.3.2 to determine fugitive methane emissions (note that the use of these factors reduces the primary data fraction, as per Section 3.6.4).

[3] Refers to coal used directly in a blast furnace, direct reduction kiln, and smelting reduction process.

Several other direct inputs with carbon content are used in the steelmaking process. As with fuel, if possible, the carbon content of these inputs should be measured to determine a site-specific emissions factor. If this is impossible, the emissions factors in Exhibit 7 can be used.

## Exhibit 7: Emissions Factors for Other Inputs

| $CO_2$ EMISSIONS SOURCE | UNIT | EMISSIONS FACTOR ($TCO_2$/UNIT) | SOURCE |
|---|---|---|---|
| Iron Ore | t | 0.037 | WSA, 2021[3] |
| Limestone | t | 0.44 | WSA, 2021 |
| Dolomite | t | 0.476 | WSA, 2021 |
| EAF electrodes | t | 3.663 | WSA, 2021 |

### 3.6.2 Electricity Emissions Factor

The GHG protocol provides two methods (location- and market-based) for determination of an electricity emissions factor. The location-based emissions factor is determined using the average emissions for the grid where the consumer is located, whereas the market-based factor accounts for contractual mechanisms (such as renewable energy certificates) that a consumer may use to reduce electricity-based emissions. The GHG protocol corporate standard encourages companies to report electricity-based emissions using both the methods, as each provides different information.

For reporting using this guidance, the location- and market-based methods are acceptable. The combined use of these methods has the potential to lead to double-counting, which underreports overall emissions (e.g., a facility connected to a low-emissions grid uses the location-based method, while another facility connected to a high-emissions grid uses the market-based method to claim the same low-emissions generation sources as an input). To overcome this issue, a residual emissions factor (i.e., the average of all generation sources connected to the grid, except for those that separately sold the emissions attribute through a market mechanism) should be used. If an electric utility (or other source) provides these residual emissions factors, steelmakers should utilize these in-lieu of the location factor. Utilities are encouraged to ensure wide availability of residual emissions factor data.

With respect to electricity emissions, the unique aspect for steel producers relates to the ability to produce electricity using off-gases from the steelmaking processes (e.g., coke oven gas, blast furnace gas, etc.). Generally, the steelmaker will use these off-gases to produce electricity via one of the following:

- On-site electricity generation owned and operated by the steel producer.
- Selling the off-gas to an independent power producer (IPP) located adjected to the steel plant and then purchasing the electricity back from the IPP.

For steel producers that exported off-gases to an IPP, a calculation is required to determine if the steel plant is a net-producer or consumer of electricity (for on-site producers, this is likely not required as electricity exports or imports to/from the grid would be metered).

Steel producers need to measure the volume of off-gases exported and combine this with measured energy content and conversion efficiency (reported by the IPP). If this is impossible, the values in Exhibit 8 can be used. The total amount of electricity generated from the exported off-gases will be the sum of the energy content for each off-gas multiplied by the volume of each off-gas exported multiplied by the conversion efficiency.

## Exhibit 8: Default Values for Electricity Calculations

| PARAMETER | UNIT | VALUE | SOURCE |
|---|---|---|---|
| Coke oven gas energy content | $GJ/Nm^3$ | 19 | WSA, 2021[3] |
| Blast furnace gas energy content | $GJ/Nm^3$ | 3.3 | WSA, 2021 |
| BOF gas energy content | $GJ/Nm^3$ | 8.4 | WSA, 2021 |
| Conversion efficiency | % | 37 | WSA, 2021 |

If the total amount of electricity produced from off-gas exports exceeds the total electricity consumed, the steel producer should report the emissions from all the fuel consumed on-site (as this will be inclusive of the emissions in subsequent combustion of the off-gases). Conversely, if the total amount of electricity produced from off-gases is less than the total electricity consumed, the location-based factor should be applied to the net import of electricity (emissions from the off-gas combustion are again captured based on the fuel used on-site).

Note that a steelmaker shall not use a market-based emissions factor to reduce the emissions from off-gases-based electricity generation.

### 3.6.3 Secondary Data Emissions Factors

Secondary data emissions factors refer to those that are based on the average emissions intensity for a given production process as opposed to the carbon content of a fuel that is combusted.[19] These factors can be used to estimate the emissions for processes that the steelmaker does not operate but are required as part of the fixed boundary.

If possible, steelmakers should request actual emissions from the supplier or customer operating these processes (note that this may not be a direct supplier to the steelmaker in multi-tiered supply chains) instead of using these emissions factors. If the emissions factors listed in this section are used, the primary data fraction will be reduced (see Section 3.5.4).

#### 3.6.3.1 Emissions during Processing

Processes that may not be directly operated by the steelmaker include those required to prepare the feed materials for ironmaking and steelmaking processes such as coking and sintering and some emissions-intensive downstream processes such as hot rolling. The emissions from these processes occur due to fuel use (primarily for heat), electricity consumption, and some direct process emissions (e.g., production of lime from limestone). If the steelmaker does not operate these processes, emissions data should be obtained from suppliers/customers. If this is impossible, the default emissions factors in Exhibit 9 can be used.

## Exhibit 9: Indirect Processing Emissions

| PROCESS | UNIT | EMISSION FACTOR ($tCO_2e$/UNIT) | SOURCE |
|---|---|---|---|
| Iron ore mining | t iron ore | 0.013 | Ferreira and Leite, 2015[7] |
| Coal mining | t coal | 0.04 | Mutchek et al., 2016[14] |
| Coking | t coke | 0.3 | IPCC, 2019[23] |
| Sintering | t sinter | 0.21 | IPCC, 2019 |
| Pelletization | t pellet | 0.19 | IPCC, 2019 |
| Pig iron production | t hot metal | 1.43 | IPCC, 2019 |
| DRI (natural gas) production | t DRI | 0.7 | IPCC, 2019 |
| Burnt lime production | t lime | 1.193 | WSA, 2021[24] |
| Burnt dolomite production | t dolomite | 1.213 | WSA, 2021 |
| Oxygen production | t oxygen | 0.09 | Chisalita et al., 2019[5] |
| Casting and rolling | t HRC | 0.084 | Backes et al., 2021[11] |
| Natural gas extraction | t methane | 0.6 | NETL, 2019[13] |

For iron ore mining that involves the extraction of relatively low-grade ore and requires more preliminary ore processing (i.e., grinding and concentration), the emissions from the iron ore mining process could be as high as 0.09 $tCO_2$/t of iron ore.

The emissions factor from coal mining could also vary based on the mining process used. Typically, most of the energy consumed in coal mining is electrical, implying that the emissions intensity can vary significantly depending on the energy mix of the grid. Methane emissions from the coal mine are not included in the emissions factor for the coal mining process. These fugitive methane emissions are discussed in Section 3.5.3.2.

As with all secondary data sources, due to this high level of variability in process emissions factors, steel producers are encouraged to request emissions information directly from suppliers.

### 3.6.3.2 Fugitive Methane

Fugitive methane refers to the methane gas released into the atmosphere during coal mining and along the natural gas supply chain. Fugitive methane emissions from coal mining come from methane that is trapped in the coal seams and escapes during the mining process. The amount of methane released during the coal mining process depends on various factors such as type of coal being mined, mine depth, and method of mining. Typical values of the emission factors for fugitive methane emissions from coal mines are given in the table below. These values are estimates, and the actual values can vary by as much as ±15 percent.[17]

Fugitive methane emissions can also come from different stages in the natural gas supply chain such as production, processing, transmission, and distribution. About 1.3–2.2 percent of the natural gas supplied to end consumers escapes into the atmosphere as fugitive methane. The emissions factor associated with fugitive methane emissions from the natural gas supply chain is given in the table below (assuming average fugitive emissions are 1.7 percent of the total natural gas supplied to the end-user).[13]

In the table, the GHG emission factors are given for a 20-year and a 100-year timeframe. According to the Fifth Assessment Report of the IPCC, methane has a Global Warming Potential (GWP) of 28 times that of $CO_2$ over 100 years and a GWP of 84 times that of $CO_2$ over 20 years.[1] Due to the variation in GWP values, GHG emissions associated with fugitive methane are calculated for both the time periods. Fugitive methane emissions (expressed in standard cubic feet) are also provided for reference.

## Exhibit 10: Fugitive Methane Emissions Factors

| PROCESS | UNIT | FUGITIVE METHANE (CU.FT/UNIT) | EMISSIONS FACTOR ($tCO_2e$/UNIT) | | SOURCE |
|---|---|---|---|---|---|
| | | | 20-year GWP | 100-year GWP | |
| Coal – Surface mining | t coal | 212 | 0.34 | 0.11 | Kholod et al., 2020[17] |
| Coal – Underground mining | t coal | 667 | 1.08 | 0.36 | Kholod et al., 2020 |
| Natural gas | t methane | 881 | 1.43 | 0.48 | Littlefield et al., 2017[10] |

As mentioned previously, there is considerable variability in the amount of fugitive methane emissions, especially along the natural gas supply chain. The actual fugitive methane emissions can be rather high compared with the values in the table because of various factors. There is a wide range of sensors and other methane monitoring equipment that could be deployed to measure fugitive methane emissions at the facility and source levels and in various time periods. Steel producers are encouraged to seek fugitive methane data collected using these methane monitoring technologies by their suppliers. If this is impossible, the default emissions factors in Exhibit 10 can be used. For consistency with other reporting standards, the 100-year GWP emissions factors should be used.

### 3.6.4 Share of Primary Data

As noted above, the use of indirect emissions factors can result in inaccuracies in the overall emissions intensity due to the variability in emissions observed in these processes depending on the process type and fuel (and/or energy) sources used.

As a result, it is required that, along with the emissions intensity developed using this framework, the share of primary data used to calculate the intensity is also reported. This is defined as the fraction of the emissions intensity that does not rely on the indirect emissions factors provided in Section 3.5.3. Specifically, it is calculated as follows:

$$Primary\ Data\ Share\ (\%) = \frac{Emissions\ based\ on\ primary\ data\ (CO2e)}{Total\ emissions\ (CO2e)}$$

Note that this is consistent with the primary data share calculation required under the WBCSD's Pathfinder framework.[20]

Activity data (i.e., amount of fuel, energy, and materials used to produce steel) should always be based on primary data (i.e., measured consumption at the steel production asset). As a result, the definition of primary data is determined by the emissions factor used. The relevant definitions are provided in Exhibit 11. Note that supplier data refers to the primary data from suppliers operating the relevant processes within the fixed system boundary.

## Exhibit 11: Primary Data Definitions

| ACTIVITY TYPE | | PRIMARY DATA DEFINITION | SECONDARY DATA DEFINITION |
|---|---|---|---|
| Fuels | Combustion/Use | Standard emissions factors (WSA, IPCC, EPA) or measured carbon content | - |
| | Production | Supplier data | Emissions factors in Section 3.6.3.2 or database listed in Pathfinder |
| Other material inputs | | Supplier data | Emissions factors in Section 3.6.3.1 or database listed in Pathfinder |
| Imported heat | | Supplier data | Emissions factor based on assumed fuel source for heat |
| Electricity | | Supplier (utility) data, regional[4] location-based grid emissions factor or market-based (complying with GHG scope 2 addendum quality criteria) grid emissions factor | Country or global grid emissions factor |

[4] Note that if the connected grid covers an entire country, the country grid factor may be considered primary data.

# 4 ENDNOTES


1. *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2*, “Chapter 2: Stationary Combustion,” Intergovernmental Panel on Climate Change (IPCC), 2006. https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html.
2. *Climate Change 2013: The Physical Science Basis*, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, “Chapter 8: Anthropogenic and Natural Radiative Forcing,” Intergovernmental Panel on Climate Change (IPCC), 2013.
3. “CO2 Data Collection: User Guide, Version 10,” World Steel Association (WSA), 2021. https://worldsteel.org/wp-content/uploads/CO2-data-collection-user-guide-version-10.pdf.
4. “Commission Implementing Regulation (EU) 2021/447 of 12 March 2021 Determining Revised Benchmark Values for Free Allocation of Emission Allowances for the Period from 2021 to 2025 Pursuant to Article 10a(2) of Directive 2003/87/EC of the European Parliament and of the Council (Text with EEA Relevance)”, n.d. *Official Journal of the European Union*: 87 (29), 2021. http://data.europa.eu/eli/reg_impl/2021/447/oj.
5. Dora-Andreea Chisalita et al., “Assessing the Environmental Impact of an Integrated Steel Mill with Post-Combustion CO2 Capture and Storage Using the LCA Methodology,” *Journal of Cleaner Production* 211 (February 2019): 1015–25, doi:10.1016/j.jclepro.2018.11.256.
6. *Global Logistics Emissions Council Framework*, 2022, Accessed July 29. https://cdn.flxml.eu/dyn/tpl_attributes/user_documents/user_34250_documents/2019_GLEC_Framework_July_2022_web.pdf.
7. Hélio Ferreira and Mariangela Garcia Praça Leite, “A Life Cycle Assessment Study of Iron Ore Mining,” *Journal of Cleaner Production* 108 (December 2015): 1081–91, doi:10.1016/j.jclepro.2015.05.140.
8. *Iron and Steel Technology Roadmap*, International Energy Agency (IEA), 2020. https://www.iea.org/reports/iron-and-steel-technology-roadmap.
9. *ISO 14404-3:2017 Calculation method of carbon dioxide emission intensity from iron and steel production — Part 3: Steel plant with electric arc furnace (EAF) and coal-based or gas-based direct reduction iron (DRI) facility,* 2017. https://www.iso.org/obp/ui/#iso:std:iso:14404:-3:ed-1:v1:en
10. James A. Littlefield et al., “Synthesis of Recent Ground-Level Methane Emission Measurements from the U.S. Natural Gas Supply Chain,” *Journal of Cleaner Production* 148 (April 2017): 118–26, doi:10.1016/j.jclepro.2017.01.101.
11. Jana Gerta Backes et al., “Life Cycle Assessment of an Integrated Steel Mill Using Primary Manufacturing Data: Actual Environmental Profile,” *Sustainability* 13 (6), Multidisciplinary Digital Publishing Institute (January 2021): 3443, doi:10.3390/su13063443.
12. Jonathan M. Cullen, Julian M. Allwood, and Margarita D. Bambach, “Mapping the Global Flow of Steel: From Steelmaking to End-Use Goods,” *Environmental Science and Technology* 46 (24) (December 2012): 13048–55. doi:10.1021/es302433p.
13. *Life Cycle Analysis of Natural Gas Extraction and Power Generation*, Pittsburgh: National Energy Technology Laboratory, 2019. https://www.osti.gov/biblio/1529553-life-cycle-analysis-natural-gas-extraction-power-generation.
14. Michele Mutchek et al., “Understanding the Contribution of Mining and Transportation to the Total Life Cycle Impacts of Coal Exported from the United States,” *Energies* 9 (7), Multidisciplinary Digital Publishing Institute (July 2016): 559, doi:10.3390/en9070559.
15. *MiQ Standard for Methane Emissions Performance: Main Document – Offshore*, MiQ, 2021. https://miq.org/document/miq-standard-offshore/.
16. *MiQ Standard for Methane Emissions Performance: Main Document – Onshore*, MiQ, 2021. https://miq.org/document/miq-standard-onshore/.

17. Nazar Kholod et al., "Global Methane Emissions from Coal Mining to Continue Growing Even with Declining Coal Production," *Journal of Cleaner Production* 256 (May 2020): 120489, doi:10.1016/j.jclepro.2020.120489.
18. *Net Zero by 2050*, International Energy Agency (IEA), 2021. https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf.
19. *Net-Zero Steel Sector Transition Strategy*, Mission Possible Partnership, 2021. https://missionpossiblepartnership.org/wp-content/uploads/2021/10/MPP-Steel_Transition-Strategy-Oct19-2021.pdf.
20. *Pathfinder Framework: Guidance for the Accounting and Exchange of Product Life Cycle Emissions,* WBCSD, 2021. https://www.wbcsd.org/contentwbc/download/13299/194600/1.
21. Rainer Remus et al., *Best Available Techniques (BAT) Reference Document for Iron and Steel Production*, European Commission Joint Research Centre Institute for Prospective Technological Studies, 2013. https://op.europa.eu/en/publication-detail/-/publication/eaa047e8-644c-4149-bdcb-9dde79c64a12/language-en.
22. R.J. Fruehan et al., *Theoretical Minimum Energies to Produce Steel for Selected Conditions, Carnegie Mellon University*, 2000. https://www.osti.gov/servlets/purl/769470.
23. 2019 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3, "Chapter 4: Metal Industry Emissions," Intergovernmental Panel on Climate Change (IPCC), 2019. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/3_Volume3/19R_V3_Ch04_Metal_Industry.pdf
24. "Lifecycle Inventory Study, 2020 Data Release" World Steel Association (WSA), 2021. "CO2 Data Collection: User Guide, Version 10," World Steel Association (WSA), 2021. https://worldsteel.org/wp-content/uploads/CO2-data-collection-user-guide-version-10.pdf

# 5 APPENDIX

This appendix lists the fixed system boundary, credits for by-products, and credits for exported energy under other existing guidance for calculating GHG emissions from the steel sector.

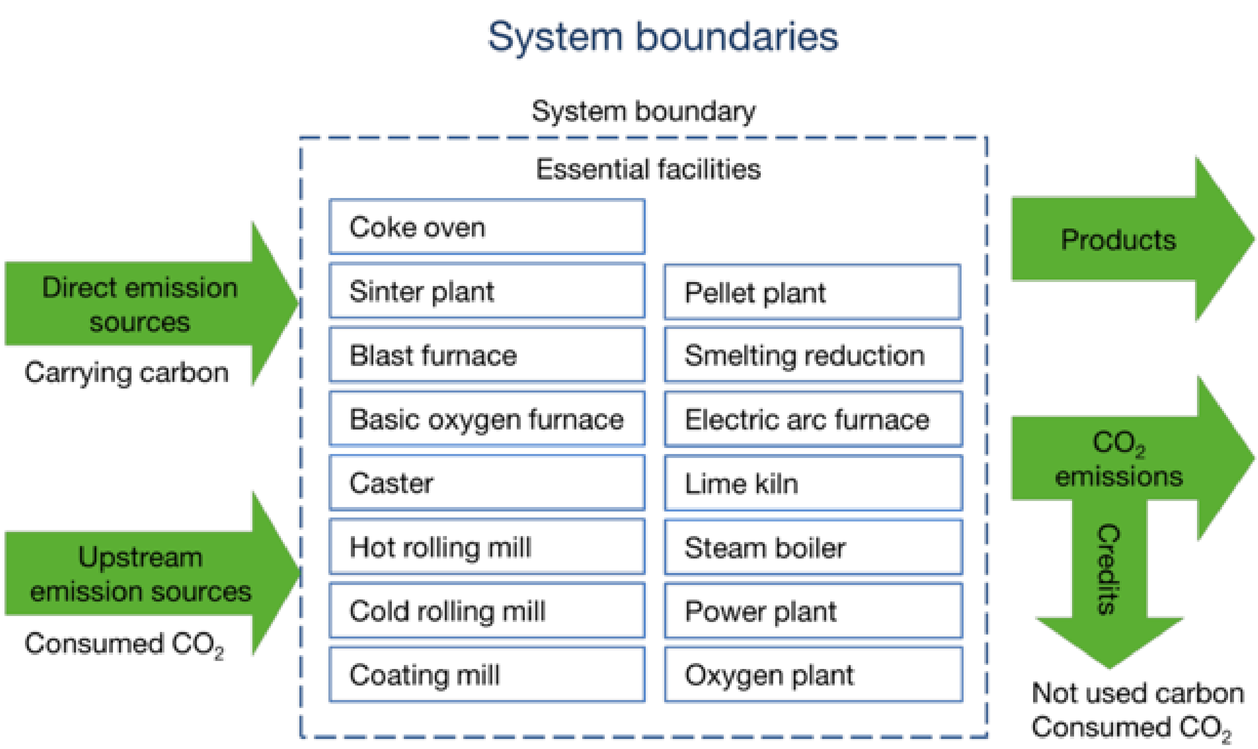
## A. Fixed System Boundary comparison

According to the Responsible Steel standard, the scope boundary for determining the GHG emissions for a site includes the following:

- Direct (Scope 1) GHG emissions
- Energy indirect (Scope 2) GHG emissions
- Upstream indirect (Scope 3) GHG emissions, including GHG emissions associated with the following:
  - Material extraction
  - Material preparation and processing
  - Transportation

The boundary for estimating GHG emissions from steel manufacturing according to the World Steel Association and the ISO 14404 standard are given in Exhibits 12 and 13, respectively.

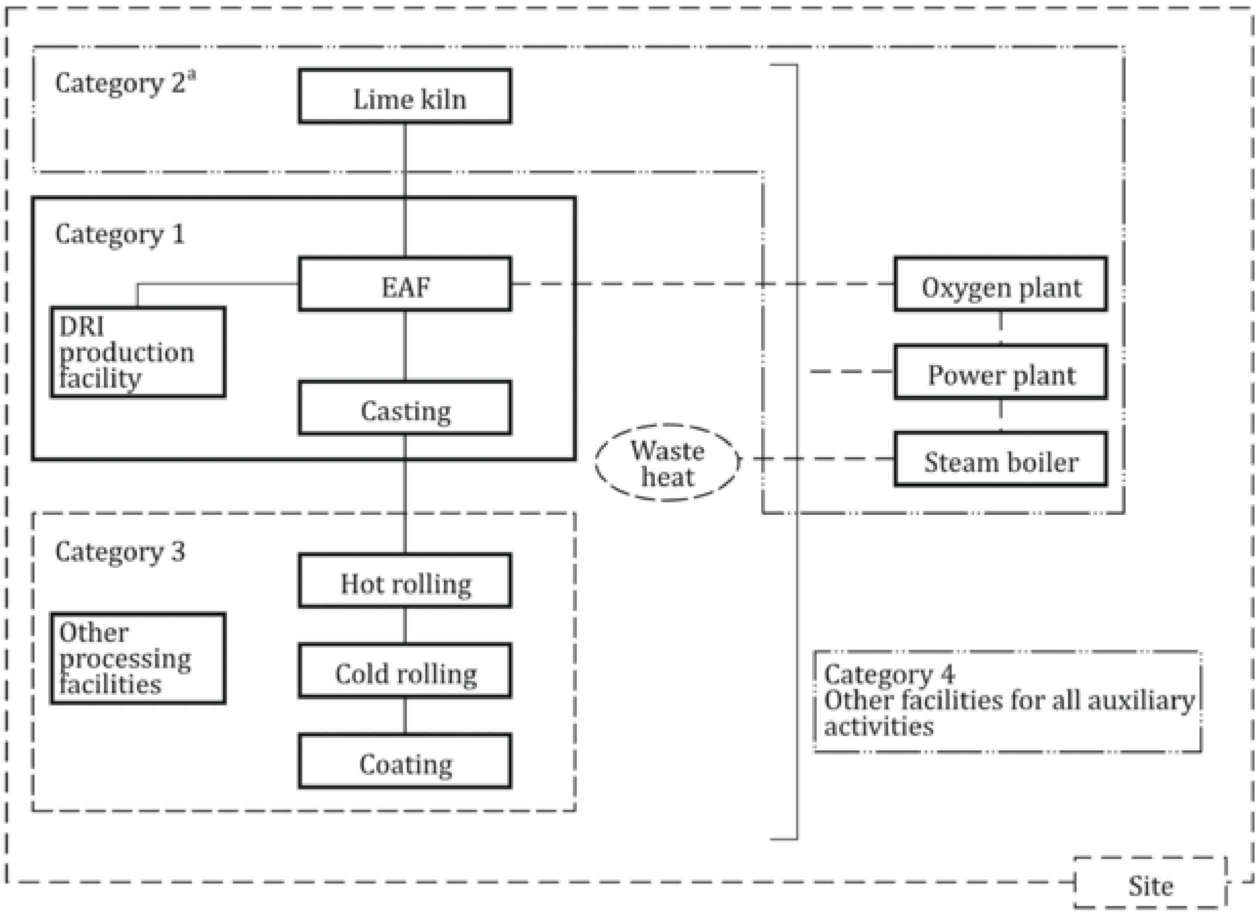
## Exhibit 12: System Boundary according to World Steel Association




**Upstream value of mining and transport is excluded from the system boundary.**

Source: World Steel Association *CO2 Data Collection User Guide 2021*[3]

## Exhibit 13: System Boundary according to ISO 14404




Source: ISO 14404-3 *Calculation Method of Carbon Dioxide Emission Intensity From Iron and Steel Production 2017* [25]

# B. Comparison on credits

## B1. By-product comparison

**Responsible Steel**

No other allocation of GHG emissions to by-products or co-products of crude steel production.

**World Steel Association**

Slags used in other activities, replacing primary materials. Credits relate to the avoided emissions.

## B.2 Exported energy comparison

**Responsible Steel**

Power generated from the use of off-gases. The emissions reduced are calculated in accordance with the saved grid emissions for power generated from process gas using the most recent global grid intensity ($CO_2e$/kWh), as determined by the IEA.

**World Steel Association**

Emissions or credits related to the procurement/delivery of electricity and steam from site. Upstream emissions of exported co-product gas considering the potential savings in electricity generation = Upstream emission factor of co-product gas X (purchased–sold).

## Exhibit 14: Comparison Table

| EXISTING GUIDANCE | FIXED SYSTEM BOUNDARY | BY- PRODUCTS | EXPORTED ENERGY |
|---|---|---|---|
| Responsible Steel | Benchmarking point set at crude steel (i.e., excluding hot rolling) | No credits | Credits |
| World Steel Association | Does not include mining activities | Credits | Credits |
| ISO-14404 | Does not include mining activities | N/A | N/A |
| Sustainable Steel Principles | Does not include mining activities | No credits | No credits |