Steel Asset-level Emission Methodology

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Introduction

Sector background

As an essential material to industrialized economies, global annual steel production has doubled over the past two decades from 850 to 1,878 megatonnes (WSA, 2021a). Rapid industrial growth in China has underpinned this increase. China is now the world's largest producer, accounting for 56,7% of crude steel production.

The steel sector is the largest source of industrial emissions, accounting for around 8% of global anthropogenic carbon dioxide (CO_2) emissions in 2020 (WSA, 2021b). The manufacturing of steel requires significant amounts of energy. With 75% of steel production fueled with the combustion of coal, deep decarbonization will require ambitious technologies and production methods (IEA, 2017b).

In 2020, the International Energy Agency (IEA) released a roadmap that includes strategies and technologies necessary for the iron and steel sector to meet the global energy and climate goals (IEA 2020). Under the Sustainable Development Scenario (a well below 2 °C pathway), emissions from the steel industry must fall by at least 50% by 2050 relative to 2019. Furthermore, the emissions intensity of crude steel production must decrease by 58%.

Currently, steel manufactures either forge primary- or scrap-steel. Primary steel is produced in integrated steel plants in an open-hearth furnace (OHF) or basic oxygen furnace (BOF). The BOF or OHF is fed pig iron reduced in a blast furnace (BF) (de Beer et al., 2003; IEA, 2017a). BFs emit 70% of the emissions in primary steel production. In a scrap-based plant, the steel is produced in an electric arc furnace (EAF) fed by recycled steel. EAFs reduce scrapped steel (or hot metal reduced via direction reduction furnace) to produce crude steel with electrodes. With the electricity as the primary energy source (45% of emissions), the carbon intensity of the electricity grid plays a critical role in reducing the CO_2 intensity of scrap steel production (de Beer et al., 2003). Globally integrated steel plants and scrap-based mini-mills account for 70% and 30% of global production respectively (WSA, 2018b). Currently, steel manufactures either forge primary- or scrap-steel. Primary steel is produced in integrated steel plants in an open-hearth furnace (OHF) or basic oxygen furnace (BOF). The BOF or OHF is fed pig iron reduced in a blast furnace (BF) (de Beer et al., 2003; IEA, 2017a). BFs emit 70% of the emissions in primary steel production. In a scrap-based plant, the steel is produced in an electric arc furnace (EAF) fed by recycled steel. EAFs reduce scrapped steel (or hot metal reduced via direction reduction furnace) to produce crude steel with electrodes. With the electricity as the primary energy source (45% of emissions), the carbon intensity of the electricity grid plays a critical role in reducing the CO_2 intensity of scrap steel production (de Beer et al., 2003). Globally integrated steel plants and scrap-based mini-mill plants account for 70% and 30% of global production respectively (WSA, 2018b).

While the forging of scrap-steel (0.6-0.9 tonnes CO_2 per tonne steel) emits less CO_2 than primary steel (1.6-2.2 tonnes CO_2 per tonne steel), the global demand for steel exceeds the supply of recycled steel. Primary steel can also be produced in an EAF using directed reduced iron (DRI), which requires less energy than a BF. The process can be decarbonized by introducing hydrogen (produced via electrolyse) as the reducing agent, instead of gas or coal. While this process is not yet commercial ready, a few demonstration projects are underway ("HYBRIT - Fossil-Free Steel," 2020).

Document structure

The 2° Investing Initiative (2DII) developed open-source methodologies to calculate carbon dioxide (CO_2) emissions at the level of an individual asset for eight sectors (aviation, automotive, power, oil & gas, coal, shipping, cement, and steel).

This document describes the methodology step by step and suggests data sources that can be used to apply the methodology to calculate asset-level CO_2 emissions in the steel sector. Publicly available data sources were used whenever possible. The asset-level activity data is however still largely unavailable in the public domain.

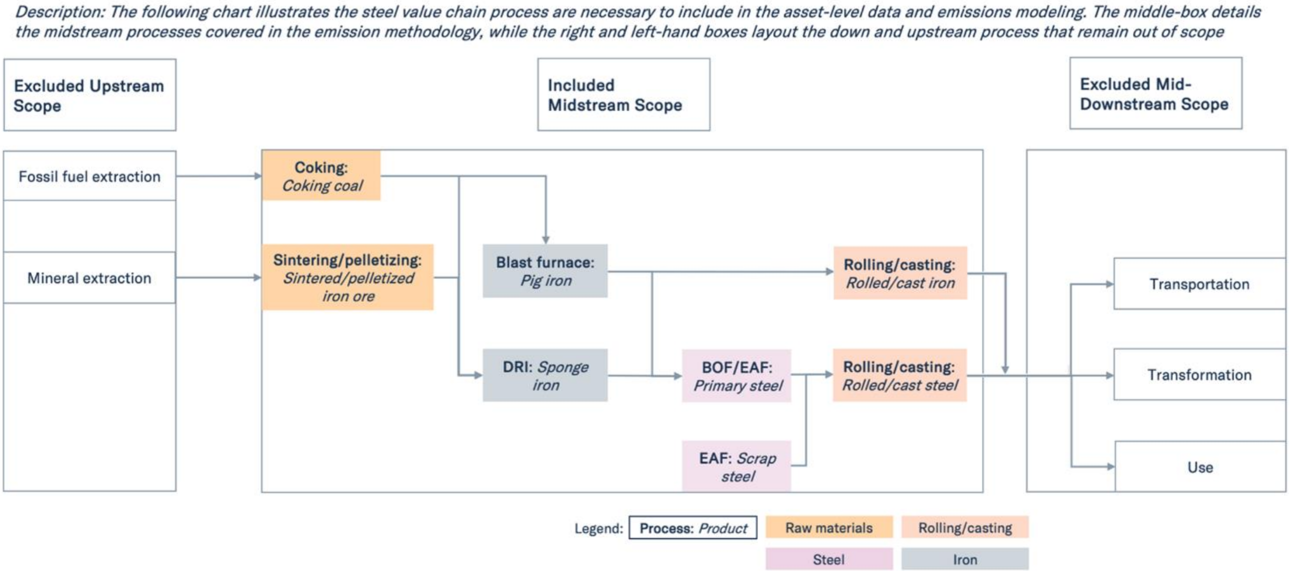
2DII works with its data spin off Asset Resolution (AR) to source asset-level capacity and/or production values and calculate asset-level emissions in the context of its research. AR sources asset-level data from leading industry data providers and carries out complementary research in house. This document gives insights into this asset-level data. Alternative sources can be used provided they comply with the data specifications as set out in the methodology.

Asset Definition

In each stage of the steel sector's value-chain, under intensive temperatures and processes, the impurities of the primary feedstock iron ore are discarded and other elements such as nickel and manganese are added to form a more robust product, steel. Other than the sourcing of raw materials, e.g., coal and iron ore mining, all these processes are often integrated into a single plant. However, the level of integration of the processes and the steel making technologies may vary from plant to plant. Likewise, the inputs and outputs of each plant are not zero-sum. A plant's coking furnace (CF) can feed the plant's BF, but any surplus coking coal could be diverted and sold for other industrial purposes (de Beer et al., 2003).

To account for this fact, for the steel sector, an asset is defined as a process within a steel plant (see Figure 1). Under the emission methodology the production values of crude steel are required, so the production is rolled-up at the level of the raw steel production, i.e., the technologies in Table 1. This means that only the *net-materials* and *net-energy* inputs required to produce the asset's crude steel are considered and not the plant's total material and energy consumption and production.

Figure 1. Steel making processes



Source: Authors, 2020 based on de Beer et al., 2003

The emission methodology is developed to calculate the scope 1 and 2 emission factor and absolute emissions for a steel plant (see Figure 2). The methodology focuses on the most energy and emission intensive steel processes (see technology types in Table 1) — coal coking, iron ore sintering, hot metal production, rolling and casting, and crude steel production. and casting The methodology does *not calculate* scope 3 emissions from raw material extraction or the steel product's life-cycle end-use.

Table 1. Asset definition

Indicator	Definition
Parameter	Asset definition
Unit	Steel plant
Description	Asset *a* (technology)
Technology	Electric Arc Furnace, Basic Oxygen Furnace, and Open-Hearth Furnace
Technology Type	Integrated Blast Furnace, Integrated DRI Furnace, Integrated Open Hearth Furnace, Mini-Mill
Identifier	Unique plant identifier
Source	Global Steel Plant Tracker (GSPT, 2021), Global Database of Iron and Steel Production Assets (GDISPA, 2021)

Asset-Level Emission Model

Emission Factor

The emission factor, expressed as tonnes of CO_2 emitted per tonne (t) of steel, reflects the asset's relative GHG impact per unit of activity. It is the ratio between the annual emissions and steel production:

$$\text{Emission factor}_{\,a,y}\left[\frac{\text{t CO}_2}{\text{t steel}}\right]=\frac{\text{Emissions}_{\,a,y}\,[\text{t CO}_2]}{\text{Production}_{\,a,y}\,[\text{t steel}]}$$

Where: a = asset, y = year

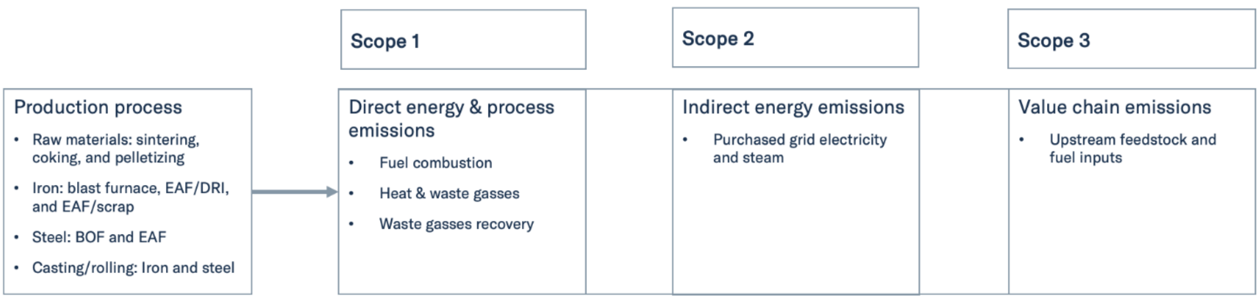
The methodology calculates the emission factors for the steel-making processes responsible for the intermediate products (pig iron, direct reduced iron, coke, pellet, sinter) and the final product (crude steel). The overall asset emission factor is calculated by aggregating the emission factor of each individual product as follows:

$$\text{Emission factor}_{\,a,y}\left[\frac{\text{t CO}_2}{\text{t steel}}\right]=\sum_{p}\text{Process EF}_{\,a,y}\left[\frac{\text{t CO}_2}{\text{t steel}}\right]+\text{Crude steel EF}_{\,a,y}\left[\frac{\text{t CO}_2}{\text{t steel}}\right]$$

Where: a = asset, y = year, p = process

Figure 2. Emission scope definitions

Description: For each process, the primary sources of emissions are identified and scoped according to standard greenhouse gas (GHG) protocol definitions (GHG Protocol Initiative, 2008).



Source: Authors, 2020 based on de Beer et al., 2003; GHG Protocol Initiative, 2008

When estimating an asset's crude steel emission factor, the preceding processes, such as the forging of hot metal in a blast furnace or the coking of coal in coking furnace, are considered. In an integrated facility, this does not cause any methodological issues. In a facility where intermediary products are sourced from various providers, it may be considered unfair to allocate all emissions to the producer of the final product, crude steel.

Absolute Emissions

The absolute annual emissions can be used to assess the absolute GHG impact of an asset compared to other assets and external benchmarks in the steel sector. The absolute emissions indicator is calculated as follows:

$$\text{Emissions}_{a,y}\ [\text{t CO}_2] = \text{Emission factor}_{a,y}\left[\frac{\text{t CO}_2}{\text{t steel}}\right] * \text{Production}_{a,y}\ [\text{t steel}]$$

Where: a = asset, y = year

Activity

When possible, the methodology applies plant-level production figures. However, actual production figures are not always available at the asset-level. In this case, the methodology estimates an asset's production by establishing an average utilization factor as a proxy (Table 3) and multiplying this by the asset's annual capacity (Table 4):

$$\text{Production}_{a,y}\ [\text{t steel}] = \text{Capacity}_{a}\ [\text{t steel}] * \text{Utilization factor}_{a,y}\ [-]$$

Where: a = asset, y = year

The granularity of the utilization factors will vary depending on the quality and breadth of the data source(s).

Table 3. Utilization factor

Indicator	Definition
Parameter	Utilization factor
Unit	-
Scope	Scope 1
Description	Annual utilization factor for asset a and year y
Value applied	e.g., 0.86
Granularity	Asset-level and country, regional, and global averages
Source	Global Steel Plant Tracker (GSPT, 2021), Latest Developments in Steelmaking Capacity (OECD, 2021), 2021 World Steel In Figures (WSA, 2020a), Steel Statistical Yearbook 2018 (WSA, 2018b), Global Steel Plant Tracker (GSPT, 2021), Latest development in Steelmaking Capacity (OECD, 2021)

Table 4. Capacity

Indicator	Definition
Parameter	Capacity
Unit	t steel
Scope	Scope 1
Description	Capacity of asset a
Value applied	e.g., 120000
Granularity	Asset-level
Source	Global Steel Plant Tracker (GSPT, 2021), Global Database of Iron and Steel Production Assets (GDISPA, 2021)

Crude Steel Emission Factor

The emission factor (EF) of crude steel (CS) production for an asset is calculated from the fuel emission factor and the electricity emission factor as follows:

$$\text{Crude steel EF}_{a,y}\left[\frac{\text{t CO}_2}{\text{t steel}}\right] = (\text{Fuel EF}_{a,p} + \text{Electricity EF}_{a,p,y})\left[\frac{\text{t CO}_2}{\text{t steel}}\right]$$

Where: a = asset, p = process, y = year

Intermediate Processes Emission Factors

The emission methodology calculates emission factors for the most emission-intensive intermediate processes involved in steel production:

- Pig iron production
- Direct iron reduction
- Coke production
- Sinter production
- Pellet production
- Steel rolling and casting

The emission factor (EF) of a specific process depends on the respective electricity emission factor, fuel emission factor and consumption factor (CF) for the process. The emission factors for the intermediate processes are calculated as follows:

$$\text{Process EF}_{a,p,y}\left[\frac{\text{t CO}_2}{\text{t steel}}\right] = (\text{Electricity EF}_{a,p,y} + \text{Fuel EF}_{a,p})\left[\frac{\text{t CO}_2}{\text{t steel}}\right]$$

Where: a = asset, p = process, y = year

Electricity Emission Factor

The electricity emission factor for a specific process is calculated from the electricity consumption factor (CF) and the electricity generation emission factor (GEF)[1] (see Table 5), is calculated as follows:

$$\text{Electricity EF}_{a,p,y}\left[\frac{\text{t CO}_2}{\text{t steel}}\right] = \text{Electricity CF}_{a,p}\left[\frac{\text{MWh}}{\text{t steel}}\right] * \text{Electricity GEF}_{a,y}\left[\frac{\text{t CO}_2}{\text{MWh}}\right]$$

Where: a = asset, p = process, y = year

The electricity share (see Table 6), and the energy consumption factor (see Table 7) are used to calculate the electricity consumption factor for each product as follows:

$$\text{Electricity CF}_{a,p}\left[\frac{\text{MWh}}{\text{t steel}}\right] = \text{Electricity share}_{a,p}\,[\%] * \text{Energy CF}_{a,p}\left[\frac{\text{MJ}}{\text{t steel}}\right] * 0.278\left[\frac{\text{MWh}}{\text{GJ}}\right]$$

Where: a = asset, p = process, 0.278 = conversion factor between MWh and GJ

Table 5. Electricity generation emission factor

Indicator	Definition
Parameter	Electricity generation emission factor

[1] All electricity emissions are assumed to be scope 2, i.e., purchased electricity (GHG Protocol Initiative, 2008).

Unit	t CO_2 per MWh
Scope	Scope 2
Description	Annual emission intensity of electricity generation for asset a and year y
Value applied	e.g., 0.100
Granularity	Country average
Source	CO_2 electricity emissions from fuel combustion 2020, Asset Resolution (2021)

Table 6. Share of energy consumption from electricity

Indicator	Definition
Parameter	Share of energy consumption from electricity
Unit	%
Scope	Scope 1
Description	Energy consumption for asset a and process p
Value applied	e.g., 10%
Granularity	Global process average
Source	International Energy Agency (de Beer et al., 2003)

Table 7. Energy consumption factor

Indicator	Definition
Parameter	Energy consumption factor
Unit	GJ per t steel
Scope	Scope 1
Description	Energy consumption for asset a and process p
Value applied	e.g., 1300
Granularity	Global process average
Source	International Energy Agency (de Beer et al., 2003)

Fuel Emission Factor

The fuel emission factor (EF) for a specific process of an asset is calculated from the fuel consumption factor (CF) and the fuel combustion emission factor (CEF) (see Table 8) as follows:

$$\text{Fuel EF}_{a,p} \left[\frac{\text{t CO}_2}{\text{t steel}}\right] = \text{Fuel CF}_{a,p} \left[\frac{\text{GJ}}{\text{t steel}}\right] * \text{Fuel CEF}_{a,p} \left[\frac{\text{t CO}_2}{\text{GJ}}\right]$$

Where: a = asset, p = process

The fuel consumption factor of an asset is calculated from the electricity share and the energy consumption factor as follows:

$$\text{Fuel CF}_{a,p} \left[\frac{\text{GJ}}{\text{t steel}}\right] = (1 - \text{Electricity share}_{a,p}\ [\%]) * \text{Energy CF}_{a,p} \left[\frac{\text{GJ}}{\text{t steel}}\right]$$

Where: a = asset, p = process

Table 8. Fuel combustion emission factor

Indicator	Definition

Parameter	Fuel combustion emission factor
Unit	t CO_2 per GJ
Scope	Scope 1
Description	CO_2 intensity per GJ of combusted fuel for asset a and process p
Value applied	e.g., 0.56
Granularity	Global process average
Source	International Energy Agency (de Beer et al., 2003)

Outlook and Limitations

The asset-level emission model develops key indicators, the emission factor, and the absolute emissions, to assess the CO_2. emissions in the steel sector. The methodology includes the most emission intensive intermediate processes as well as the production of the final product, crude steel. The main limitation of this model is the use of high-level averages for energy consumption factors and fuel consumption- and emissions factors. Further work on improving the asset-level indicator coverage, increasing the granularity of input indicators and benchmarking against external sources is underway.

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