Emissions Analysis Executive Summary

Prepared for the Steel Manufacturers Association (SMA)

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List of Abbreviations and definitions

Abbreviation	Definition
Allocated emissions	A method of attributing the Scope 1 emissions generated to a production level or process. Allocated emissions allows for product, process comparison and benchmarking between sites. Unless otherwise noted, this Report measures Allocated Emissions, not Normalized Emissions
Total direct, normalized emissions	A method of benchmarking Scope 1 emissions where total plant-wide emissions (including intermediate product sales) are divided by crude steel production in the respective year. This benchmark is comparable to ISO14404.
BFG	Blast furnace gas
BF – BOF	Blast Furnace-Basic Oxygen Furnace (i.e., the ‘integrated’ steelmaking route).
COG	Coke oven gas
Crude steel	The first point in the steelmaking production process where steel is produced (namely EAF or BOF outputs), prior to casting and further downstream processes
CCS	Carbon capture storage
DRI	Direct reduced iron, an alternative iron product produced via the DR process rather than the standard BF process
EAF	Electric Arc Furnace (i.e., the electric steelmaking route)
Flat products	Steel sheet, plate and other similarly-shaped products typically rolled from slab
HRC	Hot-rolled coil

Abbreviation	Definition
JKT	Refers to Japan, South Korea and Taiwan-China.
Long products	Steel bar and other similarly-shaped products typically rolled from bloom or billet
PCI	Pulverized coal injection, an alternative to coke in the blast furnace
Scope 1 emissions	Direct emissions occur from sources that are owned or controlled by the specific facility or plant measured
Scope 2 emissions	Scope 2 accounts for GHG emissions from the generation of purchased electricity consumed by the facility
Scope 3 emissions	Scope 3 emissions are a consequence of activities of the facility, but occur from sources not owned or controlled by the facility
MJ	Megajoules, a unit of energy to measure energy use in a specific steelmaking process. 1000 MJ = 1 GJ (Gigajoule).
MPI	Merchant pig iron
OBM	Ore-based metallics
thm	“Tonnes of hot metal”. Typically used in consumption rates (e.g. 500 t pellets /thm)
tcs	“Tonnes of crude steel”
VOC	Volatile organic compounds, a type of localized pollutant

Introduction

CRU Consulting has been engaged by the Steel Manufacturers Association (SMA) to conduct a study of US steelmaking emissions, with a focus on the relative carbon emission intensities associated with BOF and EAF-based steelmakers in the United States. The study's objective is to provide SMA with an independent assessment of EAF steelmaking emissions and how they compare with domestic and global iron and steelmaking peers.

In this document, CRU provides:

- Analysis of Scope 1 & 2 emissions for US steelmakers and description of underlying drivers
- Analysis of upstream Scope 3 emissions generated through the production of raw materials and the associated transportation of inputs to the steel mill
- Comparisons of carbon emissions between US steelmakers and global peers, at various steps in the steelmaking production process
- An overview of ironmaking-related emissions and assessment of key emissions-related factors
- Emissions benchmarking for rerollers that procure third-party slab on a total Scope 1, 2 & 3 basis

Executive Summary

Key Conclusions for the SMA

Scope 1 & 2: Domestic EAF steelmakers emit 78% less carbon emissions in crude steelmaking than their integrated counterparts in the US. At the hot-rolled steel level, the emissions standing between US EAFs and BOFs narrows to 74%

Scope 3: Scope 3 emissions for EAFs were similar to or lower than BOFs, and do not close the absolute gap between the two steelmaking routes

The carbon footprint for slab rerollers that use imported slab is higher than most US BOFs and significantly higher than all domestic EAF-based flat producers

Direct emissions for US pig iron production reached 1.47 t CO2 / thm, 15% lower than the average among Russian, Ukrainian and Brazilian peers. However, when the carbon footprint of upstream iron ore mining is included, the performance gap narrows to just 5% since US iron ore mining companies have higher emissions than their global seaborne peers

For integrated steelmaking, CRU has identified a clear relationship between iron ore quality, pellet rates, and BF steelmaking emissions. However, when all scope 3 emissions are considered, there is no overall impact on carbon intensity between domestic BFs and sheet EAFs using imported raw material. Sheet mill EAFs maintain a substantial advantage

Executive summary: Steelmaking emissions at the Scope 1 & 2 level

Crude steel production: BOFs and EAFs in the US

- The United States is home to both integrated steelmakers utilizing the BF-BOF process and scrap-based EAF steelmakers. EAF steelmakers currently contribute 70% of total US crude steel production
- Average Scope 1 & 2 CO_2 emissions for BOFs reached 1.67 t CO_2 / tcs, of which 80% is associated with the BF ironmaking stage
- Coke rates in the BF and scrap rates in the BOF are the key emissions intensity differentiators between US BOFs
- Scope 1 & 2 emissions for all EAFs reached 0.37 t CO_2 / tcs, of which 67% is associated with Scope 2 emissions (purchased electricity)
- The carbon intensity of local purchased electricity, which varies widely based on mill location, represents the key emissions intensity differentiator between US EAFs
- Industry-wide EAF emissions are 78% lower than BOF emissions on a Scope 1 & 2 basis

Hot-rolled steel: BOFs and EAFs in the US

- At the level of hot-rolled steel (both Flat products and Long products), BOF and EAF emissions intensities amounted to 1.94 and 0.48 *t CO_2 / hot-rolled steel*, respectively
- These represent a 0.27 t/t (16%) and 0.11 t/t (30%) increase in emissions intensity from upstream crude steel production, respectively
- EAFs not only have an emissions-related performance advantage at the crude steel production level, but also at the downstream casting and hot-rolling levels, typically due to newer, more efficient casting and hot-rolling equipment and processes
- Emissions associated with casting and hot-rolling are 2x higher for BOFs compared to EAFs
- For Flat-Rolled products, the emissions gap between BOFs and EAFs narrows slightly to 1.94 and 0.52 *t CO_2 / t HRC,* respectively (a 73% difference), since EAF flat-rolled producers are generally toward the higher end of the EAF emissions curve

Steel production: US and EU

- Overall US crude steel production is ~37% less carbon intensive than Europe due to the higher proportion of EAF supply in the US (70%) compared to 46% in the EU. Differences in emissions between US and EU BOFs are not significant
- While the EU has developed more regulations around CO_2 emissions, a significant portion of commodity-grade steel is produced from integrated producers using sintered fines, which increases their carbon footprint compared to the US
- For HRC and other flat products, the US uses both integrated and EAFs to produce HRC and other flat products, whereas the EU still heavily relies on integrated steelmaking or the importation of slab for downstream processing to produce HRC

Executive summary: Ironmaking emissions at the Scope 1 & 2 level

Pig iron: comparing US BFs with global peers in the merchant pig iron market

- To calculate emissions intensities for pig iron (MPI) production on a like-for-like basis, CRU assessed allocated Scope 1 & 2 emissions up to and including the blast furnace level for hot metal production. This includes emissions associated with on-site coke plants, charcoal kilns, and sinter plants, where applicable. Emissions associated with merchant pig iron casting are negligible
- The US has the lowest emissions levels for pig iron (1.47 t CO_2 / thm) among the four MPI-exporting peers. Sinter-based Ukrainian production was the highest (1.77 t/t), followed by charcoal-based Brazilian pig iron (1.74 t/t) and pellet-based Russian pig iron (1.63 t/t)
- Coke rates and relative sinter/pellet and slag rates are the key emissions intensity differentiators between US, Russian and Ukrainian pig iron
- CRU does not find the differences in pig iron emissions intensities (±12%) to be a significant competitive advantage for US pig iron producers over their global peers.
- When upstream iron ore mining emissions are included, the comparative advantage for US pig iron producers narrows even further, since US iron ore mining companies incur higher beneficiation costs (and therefore higher emissions) than global peers in the seaborne market

Ironmaking-related emissions: Relationships between sinter/pellet rates and carbon intensities

- Based on CRU analysis, high pellet rates in US blast furnaces contributes a ~0.15 tCO_2 /thm reduction in total Scope 1 emissions compared to the more sinter-intensive global average Scope 1 BF emissions factor of 1.69 tCO_2 /thm. These figures include the net emissions associated with sintering fines, where applicable
- Higher Fe (iron) content in pellets is the key performance contributor in blast furnaces. Higher Fe content reduces slag rates, which in turn, reduces coke or PCI requirements in the furnace
- High pellet use is expected to contribute to a 10% performance advantage compared to high sintered fines use, when only direct emissions in the blast furnace are compared
- While a relationship between sinter/pellet rates and BF emissions exists, other factors, like scrap rate in the BOF and the emissions intensity of upstream iron ore suppliers, also play a key role in determining overall Scope 1, 2 & 3 emissions for integrated steelmakers
- Based on CRU's analysis, the claim that sinter use (instead of pellets) has a *significantly negative impact* on integrated steelmaking emissions remains unfounded

Executive summary: Scope 3 emissions impact

Upstream Scope 3 emissions: Not sufficient to close the gap between EAF and BOF carbon footprints

- When Scope 3 emissions are included, the gap between domestic EAF flat producers and BOFs narrows moderately, since the carbon footprint of third-party purchased OBMs is included in the emissions calculation for EAFs. For some EAF flat producers, including Scope 3 emissions can more than double their on-site (Scope 1 & 2) carbon footprint
- Overall, Scope 3 emissions associated with OBM and scrap procurement increase the carbon footprint by 100% and 35%, respectively, for EAF flat and EAF longs producers
- On average, domestic EAF steelmakers emit 68% less carbon emissions, on a tCO2/tcs basis, than their US integrated counterparts when Scope 3 emissions are included. At the hot-rolled steel level, the emissions standing between US EAFs and BOFs narrows to 60%. Critically, the absolute differences do not decline. Rather, the gaps are closed simply on a percentage calculation because the denominations are enlarged
- For domestic integrated producers, upstream Scope 3 emissions calculations include external purchases or transfers of metallurgical coal, third-party coke and pellets. Overall, the carbon footprint of integrated producers increases by 25% when Scope 3 emissions are included

Scrap processing and transport emissions make only a small contribution to total steelmaking carbon footprint

- While the US scrap industry continues to face challenges associated with localized pollutants, including VOCs and particulate matter, its carbon emissions intensity is exceptionally low because of its highly localized and mechanized nature
- Carbon emissions associated with scrap processing and transport amount to less than 0.06 t CO2 / t scrap (t/t). This figure includes an estimated 0.04 t/t emissions intensity at the scrapyard (associated with shredding, ferrous separation and ancillary processes), and a further 0.02 t/t emissions associated with transporting scrap from the yard to the customer via truck, rail, barge or vessel.
- While scrap deliveries are highly reliant on higher-emitting truck transport, the scrap supply chain is highly localized. Therefore, average distances travelled are low and transport-related emissions for scrap are limited compared to other, more globalized steelmaking raw materials

Executive summary: Scope 3 emissions impact, cont.

The carbon advantage US-based BOFs have compared to other global BOFs is almost entirely eliminated when upstream iron ore mining and met coal is included

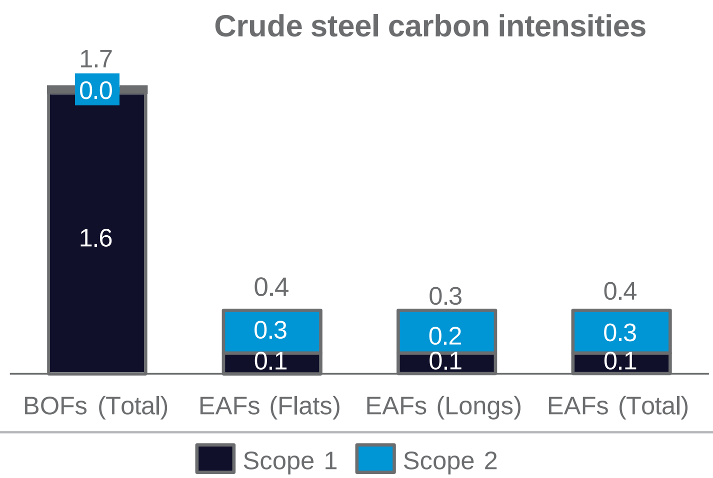
- In the US, iron ore pelletization occurs at the mine, and is therefore not included in Scope 1+2 emissions reporting for steelmakers. This contrasts with sinter-consuming BFs in Ukraine and Russia (and in much of the rest of the world), where sintering occurs at the steel mill and directly leads to a higher Scope 1+2 emission figure
- Beneficiation and processing requirements determine carbon emissions at the upstream iron ore mining level. The US has among the highest beneficiation requirements among global iron ore mining regions and, in turn, generates higher emissions on a per-ton-of-ore basis than most other regions. Overall, upstream iron ore mining adds 0.20 t CO2/thm to the carbon footprint of US BFs
- Unlike in most other regions, US integrated steelmakers meet a significant share of coke requirements via third-party purchases. Emissions associated with external coke and upstream metcoal mining contribute a further 0.21 t CO2/thm to the carbon footprint of US BFs

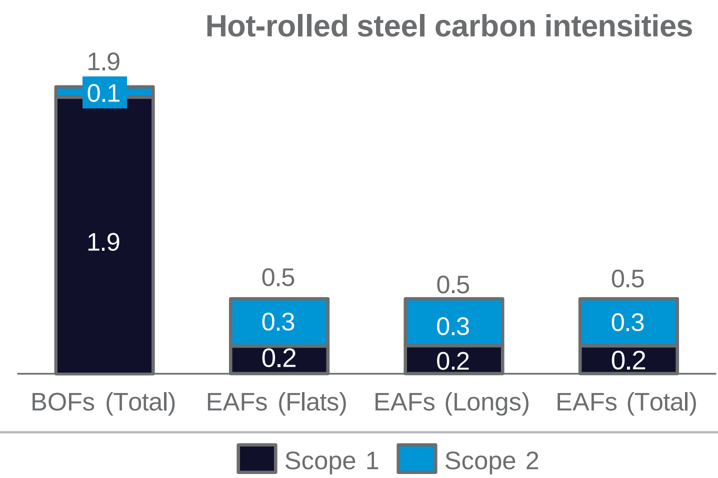
The domestic merchant slab rerolling market is characterized by high steelmaking and transport-related emissions

- The US is home to several rolling mills that currently lack a meltshop and therefore procure slabs for rerolling into HRC. Most third-party merchant slab demand is met by imports, primarily from Brazil, Mexico, Russia and India
- While Scope 1 & 2 emissions generated by slab rerolling facilities are low, they are roughly comparable to the downstream (hot-rolling) carbon footprint for domestic EAF flats producers. Therefore, the emissions intensity at the crude steel production and casting level is the key differentiator between slab rerollers and domestic flat producers
- Steelmaking/casting-related emissions for imported slab are significant but vary widely by country of origin, ranging from 2.1 t CO2 / t slab from Mexico to over 3.1 t/t from India. When associated international freight-related emissions are included, imported slabs have an average emissions intensity of 2.49 t CO2 / t slab, based on 2021 import volumes by country
- On an all-in Scope 1, 2 & 3 emissions basis, slab rerollers emissions reached 2.59 t CO2 / t HRC in 2021, which places these operations in the fourth quartile of the US HRC emissions curve. Based on this analysis, CRU concludes that the carbon footprint for slab rerollers is higher than most US BOFs and significantly higher than all domestic EAF-based flat producers

US steelmaking Scope 1 & 2 emissions: key metrics summary

Production level	Mill type in the US	US Scope 1 average t CO2 / t	US Scope 2 average t CO2 / t	Total Scope 1 & 2 t CO2 / t
Crude Steel	BOF (Total)	1.64	0.03	1.67
	EAF (Flat Products)	0.13	0.26	0.39
	EAF (Long Products)	0.11	0.23	0.34
	EAF (Total)	0.12	0.25	0.37
Hot-Rolled Products	BOF (Total)	1.86	0.07	1.94
	EAF (Flat Products)	0.17	0.34	0.52
	EAF (Long Products)	0.18	0.29	0.48

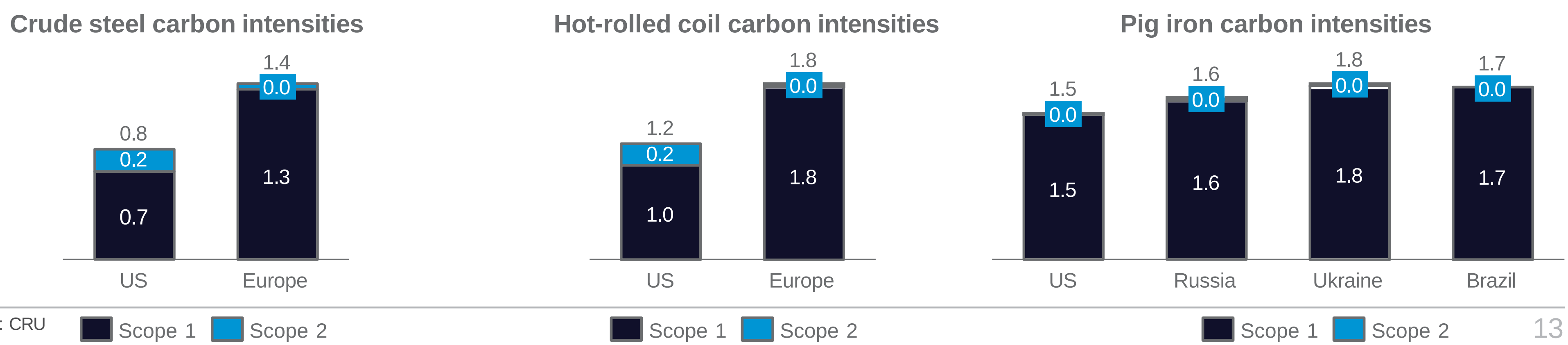




DATA: CRU

Comparing Scope 1 & 2 emissions with relevant peers: key metrics summary

Production level	Mill type in the US	US Scope 1 average t CO2 / t	US Scope 2 average t CO2 / t	Total Scope 1 & 2 t CO2 / t
Crude Steel	US (Total)	0.68	0.17	0.85
	Europe (Total)	1.31	0.04	1.35
Hot-Rolled Products	US (Total)	0.97	0.22	1.19
	Europe (Total)	1.81	0.03	1.84
Pig iron	US (Pellet + Coke BF)	1.46	0.01	1.47
	Russia (Pellet + Coke BF)	1.60	0.03	1.63
	Ukraine (Sinter + Coke BF)	1.75	0.02	1.77
	Brazil (Pellet/Sinter + Charcoal BF)	1.72	0.02	1.74



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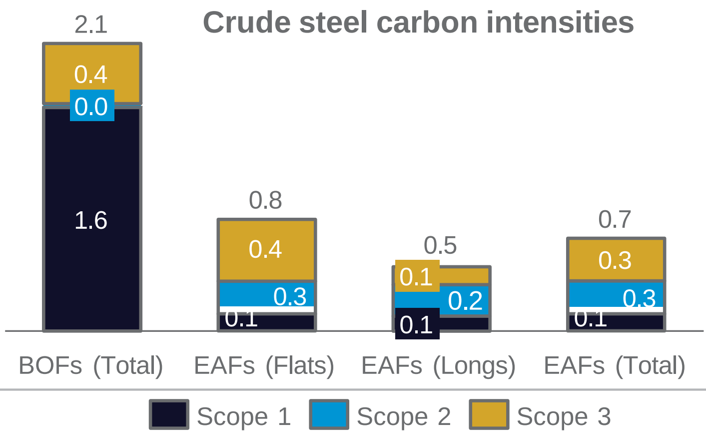
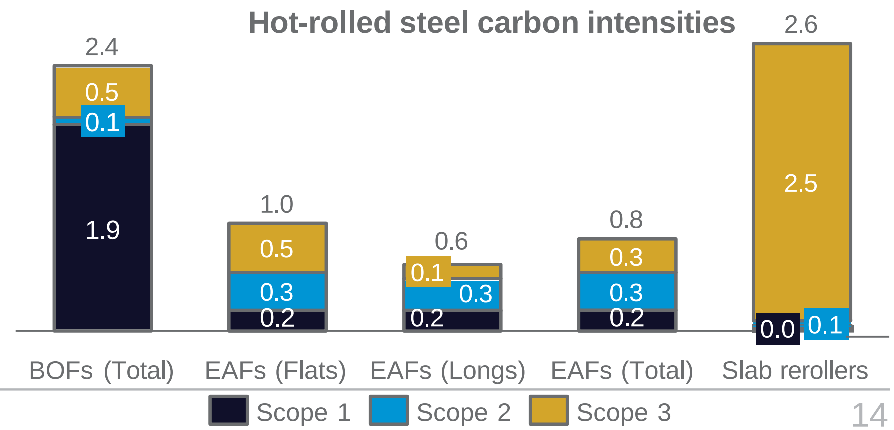
US steelmaking Scope 1, 2 & 3 emissions: key metrics summary

Production level	Mill type in the US	US Scope 1 average t CO2 / t	US Scope 2 average t CO2 / t	US Scope 3 average t CO2 / t	Total Scope 1+2+3 t CO2 / t
Crude Steel	BOF (Total)	1.64	0.03	0.44	2.11
	EAF (Flat Products)	0.13	0.26	0.43	0.84
	EAF (Long Products)	0.11	0.23	0.13	0.47
	EAF (Total)	0.12	0.25	0.31	0.68
Hot-Rolled Products	BOF (Total)	1.86	0.07	0.46	2.40
	EAF (Flat Products)	0.17	0.34	0.45	0.97
	EAF (Long Products)	0.18	0.29	0.13	0.61
	EAF (Total)	0.19	0.32	0.32	0.83
	Slab rerollers	0.04	0.05	2.50	2.59





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