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Authors
Rao, Prakash
Hendrickson, Thomas
Wachs, Elizabeth
et al.

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Testing a method for developing facility-level greenhouse gas emissions intensities of U.S. traded goods

Prakash Rao[1*], Thomas Hendrickson[1], Liz Wachs[2], Shubhankar Upasani[2], Alberta Carpenter[2*]

[1]Lawrence Berkeley National Laboratory
[2]National Renewable Energy Laboratory
*Corresponding authors: prao@lbl.gov; alberta.carpenter@nrel.gov

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Summary

This paper tests a methodology proposed by a U.S. government interagency working group for calculating a facility-level U.S. national average greenhouse gas emissions intensity for a selected traded good. The testing of the method relies on publicly available data from the U.S. government supplemented by for-purchase data. To draw practical insights, a pilot product is selected for this initial test (cold-rolled stainless steel with width less than 600mm). Lessons learned based on the results of testing the method with this product include: 1) the level of product specificity chosen should consider the emissions and production data availability for the product, particularly with respect to the product's supply chain, production pathways, and any co-products from its production, and 2) more granular, nonpublic microdata collected by the U.S. government include additional relevant details that may address gaps in publicly available data and hold promise towards successfully applying the U.S. government proposed method.

This paper is intended to provide a preliminary assessment of data availability, potential pathways for calculating scope 1 and scope 2 emissions from industrial facilities, and related challenges and potential remedies. As such, it draws its findings based on testing one product. Extension of any findings from this paper should be corroborated with results from testing additional products. Findings reported in this paper are preliminary and meant to inform potential future work to assess data needs and availability for determining facility-level greenhouse gas emissions intensity of a traded good. This paper is the first of an envisioned series reporting on methods for benchmarking facility-level greenhouse gas emissions intensities of U.S. products.

Introduction

In 2023, the European Union adopted the Carbon Border Adjustment Mechanism (CBAM), requiring manufacturers of covered products to calculate and disclose the facility-level CO_2 emissions of traded goods and pay an import fee based on this emissions intensity. In addition to the European Union, several U.S. trade partners are increasingly evaluating mechanisms based on measuring and reporting of facility-level greenhouse gas (GHG) emissions intensities to level the playing field for their domestic producers. For example, U.S. trade partners such as the United Kingdom, Canada, and Australia are implementing or considering GHG emissions-related fees on imports.

Significant disparities exist across countries in environmental performance (e.g., energy use, air pollutant emissions) of industrial manufacturing sectors. These disparities emerge due to differences in national and subnational environmental regulations, the makeup of electricity generating resources, energy grid efficiencies, and domestic producers' investments in more environmentally advanced production processes. Such disparities may lead to cost advantages for producers in countries with weaker environmental regulations or where domestic producers have not made such investments.

U.S. industrial manufacturers demonstrate several comparative advantages in this regard, having access to advanced manufacturing technologies, decades of demonstrated compliance with strict domestic environmental policies, and a relatively low-carbon electricity grid. These factors enable U.S. firms to potentially manufacture some of the lowest GHG emissions-intensive products in the world.

Existing U.S. industrial emissions data collected for other purposes presents challenges for disaggregation, timeliness, and transparency to facilitate the U.S. government (USG) to demonstrate the low emissions profiles of U.S. industries for the purposes of international trade. To demonstrate this competitive advantage, the U.S. government needs to establish a consistent, accurate, and transparent method to assess the facility-level GHG emissions intensity (hereafter referred to as facility-level emissions intensity) of U.S.-manufactured traded products using USG data.

This report presents a preliminary evaluation of public data for use in a proposed general method developed by a USG interagency working group to estimate the facility-level emissions intensity of U.S. manufactured traded products. The report tests the method with a selected traded good (a specific steel product) and reviews publicly available and for-purchase data sources that can be used to perform such calculations. The report identifies challenges and potential solutions associated with the use of publicly available data in the USG proposed method. This paper is the first of an envisioned series reporting on methods for benchmarking facility-level emissions intensities of U.S. products.

Background

U.S. trade partners that have implemented or are considering a CBAM (or similar GHG emissions intensity fee on imports) must consider how to apply an import fee. This import fee may be based on: 1) the national average product emissions intensity of the exporting country; 2) the actual emissions intensity of the specific imported product as declared by the importer (based on the producer's data); or 3) a combination of the two. Either a company-specific value can be required, or if the importer is not able to or chooses not to declare the specific emissions intensity of the product, a country-wide facility-level emissions intensity (the default value) may be an option.

There are efforts underway to develop a global standardized, third-party-verified approach to measuring GHG intensities of traded goods at the company/facility level for a traded product, for example the U.S. Environmental Protection Agency's (EPA's) Construction Material Opportunities to Reduce Emissions (C-MORE) project[1]. Other jurisdictions, such as the EU CBAM have their own requirements. There is no existing U.S. government effort to calculate U.S. national average facility-level emissions intensities for use in international trade and policy assessments. The goal of the methodology outlined in this report is to fill that gap by developing a clearly defined, publicly available (whenever possible) measure of facility-level emissions intensity for emissions-intensive product categories that are traded based on aggregated U.S-based facility level-data, across all relevant product categories.

This report weighs multiple criteria to evaluate potential methodologies for this national average facility-level emissions intensity metric for traded goods, including:

- **Data availability**: Facility-level emissions intensity data should be publicly available (whenever possible) or derived from existing USG sources for the U.S. and other producing countries at the product level in which trade measures are applied.
- **Accuracy**: The data and methodology should produce unbiased measurements or estimates and be auditable and transparent.
- **Interoperability**: The data and methodology should be standardized to allow for cross-country comparisons of products. The methodology should be recognized by trade partners and relevant industries as authoritative.
- **Scope**: The data and methodology should, to the extent practical, include both direct and indirect GHG emissions.[2]
- **Timeliness**: The data should be updated and verified on a regular basis.
- **Adaptability**: The methodology should allow for improvements in emissions measurement technologies.

[1] https://www.epa.gov/greenerproducts/cmore

[2] More specifically, it should cover scope 1 emissions (i.e., emissions from the process of making the product) and scope 2 emissions (i.e., emissions from electricity used). See the "Methodologies and Data Challenges" section for more detail.

- **Cost**: The methodology should not require firms or agencies to take on significant data collection burdens or financial costs beyond what is needed to meet the other criteria.[3]

Project Scope and Goals

This project seeks to assess the feasibility and accuracy of developing a national average facility-level emissions intensity for a pilot product using available methods and data from reports and literature. To evaluate the facility-level emissions intensity of different product categories[4], data are needed for the emissions from every manufacturing facility on an annual basis (whenever possible) along with the corresponding annual production of single or multiple products[5]. Given sufficient publicly available data, a national average facility-level emissions intensity (e.g., kg CO_2e/kg product) could be developed by either summing emissions across all facilities and then dividing by the total production (if individual facility production data are unavailable) or taking an average emission intensities across all facilities if facilities have both emissions and production data. With information on the facility-level emissions and emission intensities, it is possible to understand the range of facility-level emissions' intensities and calculate mean, median and other quartile or percentiles at the regional or national level.

GHG emissions are frequently classified into different categories depending on whether they result from the production facility, the power generation sector or elsewhere in the value chain or use phase. This assessment uses the GHG Protocol's[6] and the EPA's guidelines for reporting which include three "scope" categories (Figure 1)[7]:

- *Scope 1* reflects direct emissions at the facility level. This includes process emissions and on-site combustion emissions for equipment and vehicles[8].
- *Scope 2* includes emissions from purchased electricity, steam, and heating and cooling used at the facility. This study limits scope 2 emissions to electricity purchased at each facility. Additional product studies may need to incorporate steam, and heating and cooling loads.
- *Scope 3* reflects all "upstream and downstream" emissions associated with supply chains beyond scope 1 and 2 (see Figure 1) but is not considered in this study.

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[3] Working with trade partners to achieve an interoperable approach to climate and trade policies could help to lower the compliance costs for exporting firms, avoiding a patchwork of different data collection requirements for different markets.

[4] See the "Product Definitions" section for more details on how products are defined and categorized for this and similar product emission assessments.

[5] Manufacturing facilities could include a series of facilities or entities, depending on the product category and assessment scope. If a facility manufactures multiple products, this will need to be factored into the calculations to properly attribute emissions to the appropriate end products. For this assessment, see the "Assessment Scope" section for the facilities and processes included.

[6] https://ghgprotocol.org/

[7] https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance

[8] For this assessment, vehicle emissions are not considered due to data limitations. See the "Direct Facility Emissions - Scope 1" section for more details.

Figure 1 shows scopes 1-3 as defined by the EPA and GHG Protocol's Standards & Guidance, annotated by what is currently included in this study.

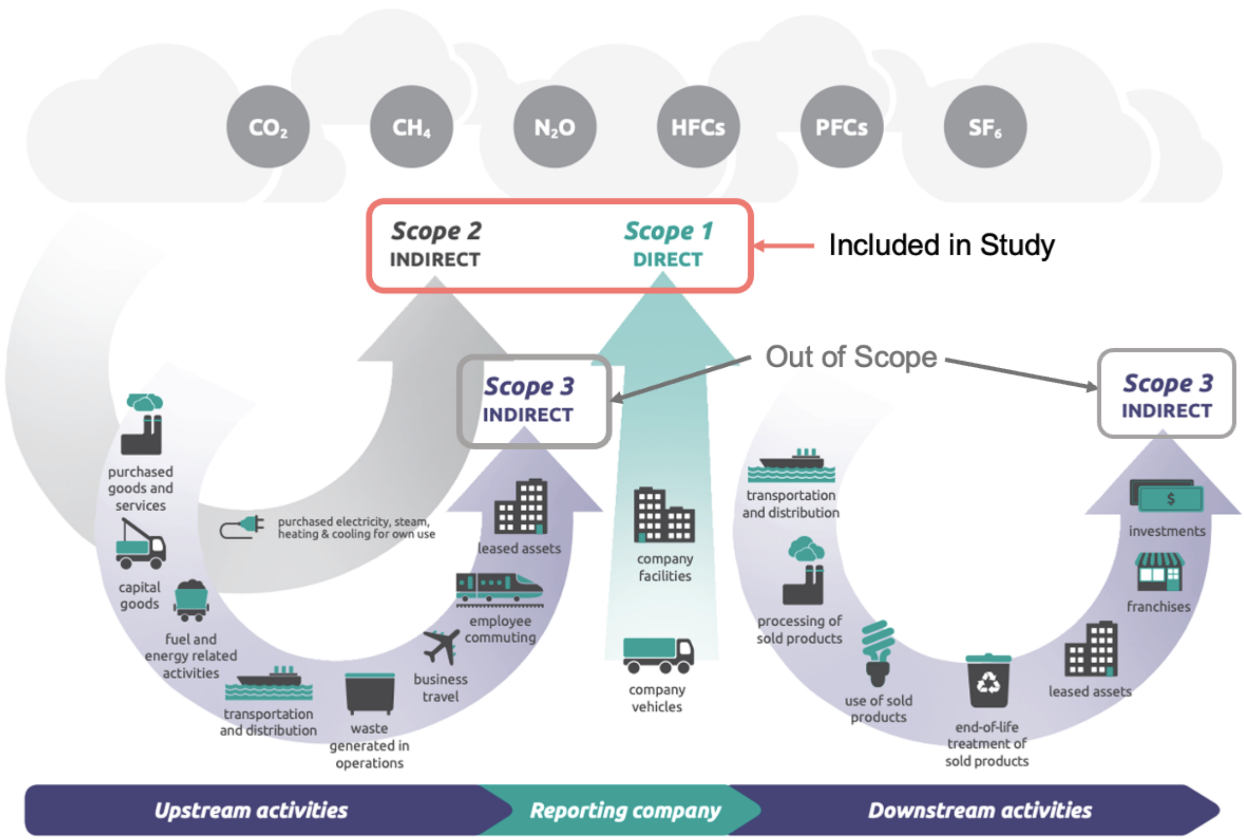

Figure 2. GHG Protocol scopes for GHG accounting modified by what is included in the current scope of this study[9]. Note that for scope 2 emissions this assessment only considers purchased electricity by a facility.

There are two broad approaches to determining scopes 1 and 2 emissions:

- A *bottom-up approach* to characterize energy consumption and emissions for each product production pathway. Energy consumption and GHG emissions are then determined at each production facility based on the production pathway and level of production (i.e., total annual metric tons produced) and aggregated up to create a national inventory and average facility-level emissions intensity.
- A *top-down approach* that uses industry-wide energy consumption, GHG emissions, and total production data to create a total national average emissions intensity of production. To obtain facility-level data, emissions would have to be allocated and disaggregated from the national-level data.

Both approaches have advantages and disadvantages, which are summarized in Table 1.

[9] Image used with permission from World Resources Institute. https://ghgprotocol.org/sites/default/files/2023-03/Scope3_Calculation_Guidance_0%5B1%5D.pdf

Table 1. Advantages and disadvantages of the general approaches considered.

Method	Accuracy	Time/Data Intensity	Uncertainties
Bottom-Up	Highest potential detail in estimations through process-level energy intensity, but accuracy is reliant on quality and granularity of data.	Highest time and data intensity to create process-level estimates that must be scaled up to a national/industry- wide scope.	Facility processes and efficiencies can vary significantly, creating a limited number of estimates and scaling those will not capture those variations. Care must be used to ensure compatibility of data sources (e.g., fuel sources, electricity grid GHG emission intensity).
Top-Down	Capable of capturing the highest amount of emission sources, but at a low level of granularity. Accuracy is dependent on how inclusive the data source is for industrial emissions.	Lower time and data intensity, but dependent on the quality and breadth of the data sources used. Increased accuracy may require the combination of multiple data sources to capture emission sources.	Top-down data sources may not include all emission sources, such as the EPA GHG Reporting Protocol (GHGRP) emissions under the reporting threshold. Care must be used to ensure compatibility of data sources (e.g., system boundaries). Electricity emissions may not reflect the specific generation sources used.

In the following sections, the USG proposed method for a bottom-up assessment of scopes 1 and 2 emissions at the facility-level using publicly available data are presented and discussed. Top-down approaches are assessed for comparison as needed. The sections walk through the definition of the pilot product selected for testing the USG proposed method, assessment scope, and detailed method assessment, including key data sources, for scopes 1, 2 and product production data to generate a facility-level emissions intensity. Beyond this, the study identifies gaps in the public data and future work needs, including potential alternative approaches to improve accuracy, harmonizing data sources, and future pilot product assessments.

Proposed U.S. Government Interagency Working Group Method

Recognizing the challenges that U.S. industry may face in foreign markets that apply a GHG emissions intensity-related import fee, USG agencies[10] developed a potential method for determining facility-level emissions intensity of a product-by-facility based on existing USG statistical sources, some of which are publicly available (e.g., EPA GHGRP) and some of which are not due to confidentiality requirements (e.g., facility level census microdata).

This method is intended to generate a national average and distribution of emissions intensities at the facility level. This can be a first step to inform a U.S. national baseline or default facility-level emissions per unit of production within a given product category. It is not intended to be used for product comparisons for purchasing decisions, nor to represent any specific manufacturer's product or facility's emissions. Nevertheless, the eventual deployment of this method requires, as will be shown, accessing the microdata, or confidential business information (CBI) from the mentioned Census products. This data requires an approval process including permission for disclosure of the relevant data.

The objective of the USG proposed method as drafted by the drafting agencies is:

For a given product category, characterize the distribution of GHG intensities from direct and indirect emissions across U.S. facilities. In an ideal scenario, this can be constructed if the U.S. government observes direct and indirect GHG emissions and output at the product-by-facility level annually and for the entire population of U.S. facilities. One can then divide total (i.e., sum of direct and indirect) GHG emissions over output at the product-by-facility level to construct GHG emissions intensity at the product-by-facility level for all U.S. facilities. Representative measures of GHG intensity could then be calculated – for example by taking the mean, median, or some other quartile or percentile from the distribution of GHG intensities across facilities[11].

The USG proposed method as drafted by the USG agencies is as follows:

- Scope 1 emissions: *This approach uses product-by-facility level output quantity data from the Census Bureau's Economic Census[12], collected every five years. Quantity data is merged at the facility level to on-site direct GHG emissions data from EPA's GHG Reporting Program[13], collected annually for roughly 8,000 facilities. The resulting product-by-facility GHG intensity is the ratio of direct GHG emissions to output, computed every five years. The representative direct GHG intensity for a product could*

[10] Agencies contributing: Department of Commerce, Department of Energy, Department of Transportation, Department of Treasury, Environmental Protection Agency, U.S. Trade Representative, General Services Administration
[11] U.S. EPA has previously performed this type of calculation for Cement and Glass plants using GHGRP data. See factsheets at the bottom of this page: https://www.epa.gov/ghgreporting/ghgrp-minerals
[12] https://www.census.gov/programs-surveys/economic-census/year/2022/about.html
[13] https://www.epa.gov/ghgreporting

be the mean or median of product-by-facility-level GHG intensities or any other quartile or percentile within the GHG intensity distribution, provided it satisfies Census data disclosure requirements. Furthermore, this approach has the advantage of using the same datasets that cover multiple products, creating GHG intensity measures that are comparable across products.

- <u>*Scope 2 emissions*</u>*: The U.S. government could also work towards constructing indirect, scope 2 U.S. emissions using a bottom-up method with administrative data. For example, energy input data from DOE's Manufacturing Energy Consumption Survey (MECS - currently conducted on a quadrennial basis), the Economic Census or the Annual Survey of Manufactures (ASM; now subsumed into the Annual Integrated Economic Survey (AIES))[14], combined with grid-level GHG emissions intensity data from the electricity sector, can be used to obtain scope 2 emissions.*

Testing the proposed USG Method and Data Challenges

In the following section, we detail data needs and challenges associated with developing a national facility-level emissions intensity for a specific product using publicly available data as outlined in the USG proposed method.

Product Definitions

Economic goods involved in international and national trade are classified according to standardized classification systems including the Harmonized Commodity Description and Coding System (HS) and the North American Industry Classification System (NAICS). A review of these systems is important as one (HS) is used for trade whereas another (NAICS) is often used when reporting data. Understanding each enables connecting data to a product of interest.

The first two digits of the HS code refer to the HS chapter, the second two refer to headings, and final two digits refer to sub-headings; this gives a total of six digits used internationally. Some countries append additional digits to these HS codes; the United States adds an additional 4-digit code to classify imports (according to the harmonized tariff system) and exports (according to schedule B). The European Union appends two digits to the HS codes in their combined nomenclature system (CN). HS codes cover 98% of goods and over 5,000 commodities in international trade. While HS codes cover goods traded globally, NAICS codes are classifiers for the North American market and are used to categorize businesses by type of economic activity. The first two digits of the NAICS code refer to the economic sector, third refers to the subsector, fourth refers to the industry group, fifth designates the industry, and the sixth digit designates the national industry. A zero as the sixth digit generally indicates that the

[14] Confidential business information (CBI) in these products contains facility-level data; see the section on "Accessing and Using Census Microdata"

NAICS industry and the U.S. industry are the same. HS codes are tied to a specific product description whereas NAICS codes show a product manufacturer type rather than a product type.

Pilot Steel Commodity Background

The USG proposed method was designed to be used for a range of products that have been designated as covered products in existing or contemplated border measures, including aluminum, iron and steel, nitrogenous fertilizers, cement, flat glass and asphalt binder. All of these products are energy-intensive commodities and have a high value and volume of trade. Emissions data from facilities for these products exist in the GHGRP. While the U.S. imports and exports a portion of all of these materials, trade is particularly important for steel and aluminum[15].

For this paper, one product, cold-rolled stainless steel with width less then 600mm within HS Code 722020, was chosen to demonstrate the USG proposed methodology and pilot the calculation process of facility-level emissions intensity. This project selected a very specific piloted product type as trading partners may assess products at this level. It is therefore critical to understand and track the difficulties and implications for calculations related to such specific products and begin to evaluate alternate approaches should it prove difficult to comprehensively determine facility-level emissions intensities at this specific level. Traditionally, the U.S. has been a large producer of steel, and steel products represent high value exports. The steel sector has a significant economic impact in the U.S. The U.S. steel industry employs large numbers of workers (200,222 jobs in June 2024 reported in NAICS codes 3311 Iron and steel mills and ferroalloy manufacturing, 3312 Steel product manufacturing from purchased steel and 33151 Ferrous metal foundries)[16]. It also serves as a building block for construction, automotive and energy products, so the product represents a strategic part of the economy.

At the same time, the U.S. steel industry has made key investments to electrify steel production over the past two decades. The electricity-based steelmaking approach is a much less emissions intensive method for producing steel than traditional processes (see the “Assessment Scope” section for more details). As of 2022, 72% of steel production was from electric arc furnaces[17], an inverse of the global production average, which is 71.1% from the traditional blast furnace and basic oxygen furnace (BF-BOF) production path[18]. This is the primary driving force behind the U.S. top-line comparative advantage in terms of GHG emissions[19] as described in the next section.

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[15] Roughly 80% of emissions covered by EU CBAM may be associated with iron and steel imports according to https://www.spglobal.com/commodity-insights/en/news-research/latest-news/energy-transition/022423-infographic-cbam-countries-hit-hardest-eu-carbon-border-tax
[16] Data from the Quarterly Census of Employment and Wages, accessed January 9, 2025 https://www.bls.gov/cew/
[17] https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-iron-steel.pdf
[18] https://worldsteel.org/data/world-steel-in-figures-2024/
[19] See for example Hasanbeigi, 2022. Steel Climate Impact: An International Benchmarking of Energy and CO2 Intensities, which places U.S. second in the world in 2019 for total CO2 intensity per t crude steel (Figure ES1)

Production Pathways

In examining GHG emissions from steel production, two distinct pathways for generating steel products: BF-BOF in integrated steel mills, and electric arc furnace (EAF) in mini steel mills (minimills) are considered. Figure 2 shows a high-level process diagram for how steel products are generated through these pathways.

The integrated BF-BOF mills are more emissions-intensive, utilizing primarily coal and coke in production. The EAF mills use scrap steel with supplemental iron coming from iron oxide reduced with natural gas and/or a syngas (e.g., hydrogen and carbon monoxide), and then electricity in crude steel production. EAF uses a larger share of recycled steel in production than BF-BOF. Out of either the EAF or BF-BOF operations, molten steel is casted into crude steel. Downstream of the crude steel and continuous casting, the product must undergo further refining, such as hot rolling with additional cold rolling or alloying for some products. In the case of this assessment, the goal is to develop a facility-level emissions intensity (e.g., kg CO_2e/kg product) for each facility involved in the processing of cold-rolled stainless steel, less than 600mm wide.

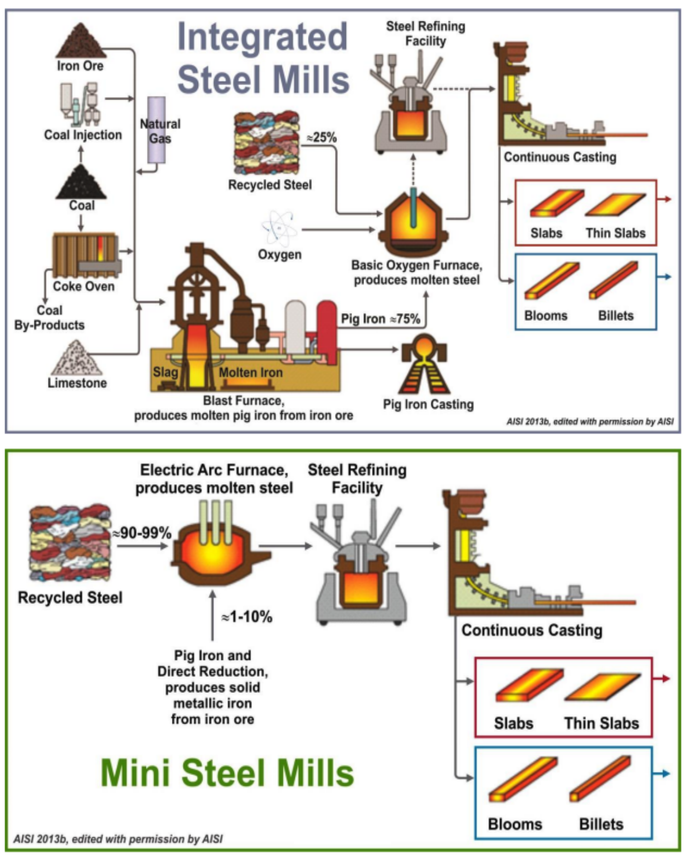

Figure 2. High-level process diagram of two primary pathways for manufacturing steel products.[20]

[20] https://www.energy.gov/sites/prod/files/2019/05/f62/AHSS_bandwidth_study_2017.pdf

Direct Facility Emissions - Scope 1

Scope 1 GHG emissions intensities can be expressed as:

Scope 1 emissions intensity = scope 1 emissions divided by physical production output

Manufacturers emitting more than 25,000 metric tons of CO_2e per year are required to report their scope 1 emissions annually to the EPA via the GHGRP[21]. Additionally, all facilities in select sectors, including Cement, Aluminum, Ammonia, Refining, and others regardless of annual emissions outputs are required to report to the GHGRP. The reported data is published online and includes information such as total reported emissions broken down by emission-type (e.g., methane, CO_2) and source (e.g., direct combustion, iron and steel processing). For sectors where all or a majority of facilities are required to report, the GHGRP can be a valuable public source of emissions by facility.

To determine representativeness of the GHGRP, another data source that enumerates the U.S. facilities within a sector is needed. There is no publicly available listing of all steel facilities in the U.S. However, to continue testing the USG proposed method, for-purchase public sources were sought. In the case of Iron and Steel, the Association for Iron and Steel Technologies (AIST) releases an annual report listing U.S. iron/steel facilities along with pertinent information needed for applying this method, such as location, annual production for blast furnaces (in metric tons of hot metal), and annual production capacity (different from annual production) for electric arc furnaces (in ,metric tons of metal)[22,23]. These reports are available to the public for purchase and are used here due to the unavailability of free publicly available production data for steel. It should be noted that such reports may not be available for every sector of interest. In these cases, other methods will be required to understand the representativeness of the GHGRP. In addition to a review process with trade associations and industry representatives, this could include identifying the emissions from the sector at the national-level and comparing it to the sum of the emissions listed in the GHGRP for the sector.

A comparison of the coverage of the GHGRP for the Iron/Steel sector to the AIST data sets is shown below in Table 2. Note that the GHGRP lists 120 facilities within the 331110 NAICS designation, however 22 of these facilities did not report any emissions from iron/steelmaking. Instead, all 22 facilities listed emissions solely for stationary combustion. While these facilities are likely doing secondary processing of steel, they have been excluded from the table below as this was not confirmed.

[21] See https://www.epa.gov/ghgreporting/learn-about-greenhouse-gas-reporting-program-ghgrp for specifics as to which facilities are required to report emissions; 25,000 metric tons of CO_2e per year is a common benchmark, but certain industries are required to report regardless of whether this threshold is met.
[22] 2024 AIST North American Blast Furnace Roundup
[23] 2024 AIST Electric Arc Furnace Roundup

Table 2. Summary of steel manufacturing facility counts by AIST and EPA GHGRP.

Facility Count (2023)	AIST	GHGRP
Integrated (BF-BOF)	10	10
Minimills (EAF)	104	98

Integrated facilities (BF-BOF) are wholly covered by the EPA GHGRP. Minimills (EAF) are mostly covered with 98 of the 104 facilities represented. For the Iron/Steel sector, the GHGRP appears to be a good source for scope 1 emissions at the facility-level. When applying the method to other sectors, this determination should be made to ensure the GHGRP has good coverage. If it does not, then an alternate data source is required to supplement for the facilities not listed in the EPA GHGRP. There is no other known publicly available, annual national-level inventory of industrial scope 1 emissions by facility.

At the state-level, additional data sets may be available. For example, in support of their cap-and-trade program, the California Air Resources Board maintains a listing of scope 1 emissions by facilities for those under the cap-and-trade program[24]. Note that the requirements of California's Mandatory Reporting Rule are more stringent than the GHGRP for certain industrial sectors including iron and steel production, as the threshold for reporting in California is 10,000 metric tons CO_2e per calendar year[25].

The GHGRP and AIST data sets lacked specific detail to apply the method towards understanding the facility-level emissions intensity of the specific steel product selected for piloting yet could serve as valuable resources for estimating facility-level emissions intensity for more generalized steel products. To estimate the emissions intensity of specific steel products, datasets would need to include parameters such as quantities of steel by finished good type or emissions by specific unit operations for iron/steelmaking (e.g., emissions for hot rolling, cold rolling, flattening). It should be noted, however, that the majority of the energy consumption and accompanying emissions from iron/steel manufacturing are associated with the iron/steelmaking and not the finishing (e.g., cold rolling, pressing), particularly for BF/BOF processes[26,27,28]. For instance, in a study conducted by the DOE, the theoretical minimum energy consumption for cold rolling is 0.02 MMBtu/metric ton of product whereas it is 1.3 and 7.9 MMBtu/metric ton of product for the EAF and BOF processes, respectively[29].

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[24] https://ww2.arb.ca.gov/mrr-data
[25] See California guidelines: https://ww2.arb.ca.gov/sites/default/files/classic/cc/reporting/ghg-rep/regulation/mrr-2016-unofficial-2017-10-10.pdf
[26] https://www.energy.gov/sites/prod/files/2019/05/f62/AHSS_bandwidth_study_2017.pdf
[27] https://www.energy.gov/eere/amo/articles/itp-steel-theoretical-minimum-energies-produce-steel-selected-conditions-march
[28]For some steel products, such as stainless steel, alloying with materials like chromium or nickel is an energy intensive process and its exclusion would underestimate the facility-level emissions.
[29] Note that these are theoretical minimums and not what could be practically achieved

Given this, the GHGRP would likely be a valuable resource for estimating facility-level emissions intensity for more generalized steel products. Future efforts could examine the appropriate level or groupings of HS product categories that could be evaluated using the GHGRP while still maintaining enough specificity to capture variation in emissions intensity. Piloting the use of the GHGRP for a group of steel products that undergo similar operations, e.g., processed through cold-rolling, processed up until crude steel only, rather than choosing a specific product aligned with an HS code (e.g., 722020, stainless steel, flat-rolled, width less than 600 mm, cold-rolled), would help understand the utility of the GHGRP for more generalized products.

Another complexity arises when considering the supply chain for some steel products. Some facilities purchase crude steel from an integrated or minimill facility and form into steel products, such as flat and cold rolled stainless steel with width under 600 mm currently under examination. In these cases, one would need to include these secondary/tertiary forming facilities within the calculation scope and their source for crude steel. On the upstream side, some BF-BOF operations do not include coke making onsite but purchase coke from coking facilities. Exclusions of emissions from these upstream facilities would underestimate the emissions intensity to produce a given product.

Existing literature on the energy consumption and GHG emissions of steel production and finishing could estimate an energy (e.g., MJ/kg product) and GHG intensity at each stage of the production process. However, this would introduce an uncertainty in the facility-level emissions intensity which may be difficult to determine.

Electricity Emissions - Scope 2

Similar to the scope 1 method, scope 2 emissions are accounted for as an emissions intensity. This study captures scope 2 emissions, originating from electricity consumed at the facility, but generated upstream of the steel production operations. Scope 2 emissions are highly sensitive to regional and temporal variations because emissions are based on electricity generation mixes. These generation mixes shift continuously throughout the day, and vary substantially by location based on the availability of generation sources. The availability of generation mix data and the subsequent electricity GHG emission factors (g CO_2e/kWh) can significantly impact estimates of electricity GHG emissions[30].

The USG proposed method for testing a bottom-up approach for scope 2 requires two steps: 1) quantifying the electricity purchased by each steel facility, and 2) multiplying the electricity purchased by the emission factor of the facility's local electric grid. This requires developing an electricity intensity (kWh/kg steel product) for each production pathway, applying that intensity to each facility to obtain facility electricity consumption, and then determining facility electricity emissions at each facility based on regional electricity generation mix data and the associated

[30] https://www.sciencedirect.com/science/article/abs/pii/S0167268114000808

grid emission factor. Without this data available, an alternate approach could capture total industrial electricity consumption at a national level, where one could apply a national average electricity mix, or use regional data for electricity consumption and generation mixes to obtain a more refined emissions estimate.

An initial review of the available literature in tandem with the scope 1 assessment indicated that a bottom-up, process-level electricity intensity estimate would be limited if constrained to using only publicly available data. This could therefore create significant data gaps and uncertainties when attempting to capture industry-wide emissions.

In contrast, an alternate estimate was more feasible given the availability of steel industry-specific electricity consumption data through the MECS data (Table 3.1, Fuel Consumption - NAICS codes 331110 and 3312)[31]. The MECS data is also disaggregated by census region, which would allow us to capture regional variations in electricity generation data. However, the MECS data is only reported every four years, and the publicly available data is rolled up to the 6-digit NAICS level.

Using the census region electricity consumption data, two approaches arose to determine electricity generation mixes based on data from EPA's eGRID database[32]. An average mix for each census region could be used by aggregating the eGRID state mixes, or electricity emissions at each facility within the census regions could be determined[33]. For the second approach, MECS electricity consumption data could be allocated to each facility based on the share of each facility's production, assuming EAF facilities made up the vast majority of the reported MECS electricity consumption. This would require assuming that only EAF production would be considered in this allocation of electricity, which assumes that BF-BOF electricity consumption is minimal in comparison. Currently MECS and other publicly available data for facility production are unavailable (see the "Total Production" section for further detail). Applying the relevant state eGRID electricity emission factors to the facility electricity consumption would result in an estimate for scope 2 emissions.

Total Production

The intent for testing this method was to gather data on steel production by finished product type in physical units (e.g., tons of steel) for each facility listed in the GHGRP data set. Production values normalize the emissions values allowing for comparison across different manufacturers. Often, monetary units are used as a proxy for production. However, monetary units are sensitive to markets and fluctuate from year-to-year and region-to-region. The same production process can have two different emissions intensities for consecutive years when using monetary units solely due to price changes. However, revenue data are available publicly and often used by analysts. These are available via sources like the U.S. Census ASM (now

[31] https://www.eia.gov/consumption/manufacturing/data/2018/
[32] https://www.epa.gov/egrid/download-data
[33] Transactional methods used to offset emissions (e.g., renewable energy credits) are not currently being considered for the purpose of national benchmarking here but may have an impact on electricity grid emission factors for specific facilities.

AIES). Techniques can be applied to estimate the physical production values using revenue by multiplying by a unit cost. The accuracy of this estimate would need to be tested before confidently pursuing it.

It is preferred to use physical production units, such as metric tons of steel, as their value is not subject to external factors, such as the sensitivities of monetary units to markets. Further, energy/emissions are directly attributable to production, meaning that energy consumed (and GHGs emitted) scale with production.

The AIST data sets include some detail on production for each facility; note, as stated above, this data set is not public but available for purchase and similar sets may not be available for every sector of interest. The Electric Arc Furnace Roundup[34] includes detail on production capacity and the Blast Furnace Roundup[35] captures actual production values. There a few caveats with each, in addition to the general caveat that the production values are for all steel and not broken down by specific product types:

- Production capacity is not reflective of actual production. The former reflects the potential production output if equipment were run at capacity during all operational hours, whereas the latter reflects the quantities actually produced. In 2021, 2022, and 2023, iron and steel production capacity in the U.S. was 79%, 75%, and 74%, respectively[36].
- The Blast Furnace Roundup provides production in terms of hot metal production. This is not equivalent to finished steel. It is the hot, molten steel exiting the blast furnace before entering into the casting process. Differences between hot metal and finished steel will occur due to factors such as material losses.
- Steel may be finished by one or more third-party manufacturers. These manufacturers purchase crude steel and form it into a finished product through forging, hot rolling, or cold rolling. Therefore, a facility with the NAICS designation of 33111 could sell the crude steel it manufactured to another facility that finishes it to a product that could be of interest for this study, e.g., width less than 600 mm flat and cold rolled steel. MECS includes secondary steel facilities (under NAICS 33112), but the source of the crude steel is not denoted thereby not allowing one to assemble the supply chain for a given product to determine its corresponding facility-level emissions intensity.

If a data source of physical units of production is not available, methods to allocate the available data by product may need to be explored. This could include determining the fraction by weight of each finished steel product manufactured in the United States and applying it across all steel facilities. Not all steel facilities produce each type of finished steel product and this would lump all crude steel across all facilities together. Corrections would need to be made for crude steel imports finished at U.S. facilities. If possible, a method to determine the error associated with applying such an allocation method should be sought.

[34] https://imis.aist.org/store/detail.aspx?id=PR-RU2023-2
[35] https://imis.aist.org/store/detail.aspx?id=PR-RU2021-7
[36] https://fred.stlouisfed.org/series/CAPUTLG3311A2A

Alternatively, a determination could be made to assign a single emissions intensity for all steel produced in the U.S. and not have separate intensities for each type of finished product. In its Mineral Commodity Survey[37], the United States Geological Survey publishes the total volume of steel produced in the U.S. across all facilities (with breakdowns by EAF, BF-BOF, finished, unfinished) and could be used for this purpose. However, a significant portion of emissions may be attributable to finishing processes, e.g., when alloying with nickel and chromium as is the case for stainless steel, thereby leading to underestimates/overestimates in the actual emissions intensity for a given product. This may be more relevant for minimill operations than BF-BOF integrated mill operations because the EAF emissions intensity is much lower than the BF-BOF emissions intensity making emissions intensity of finishing more prominent in EAF operations than integrated mill operations.

Ultimately, any method chosen should indicate 1) a level of product specificity needed for the product being evaluated, 2) whether the method is intended to be applied to a specific production pathway, averaged across all pathways, or both, and 3) an acceptable uncertainty for the facility-level emissions intensity calculated which would allow for understanding acceptable error ranges for the results.

Further considerations

This study is intended to be the first in a series of assessments toward developing national facility-level emissions intensities of key traded products. Future assessments could focus on different products, develop quantitative estimates, or expand the scope of the assessment.

Future Work

Testing this method with the pilot steel product selected using publicly available data revealed several challenges to producing a facility-level emissions intensity at the level of specificity of the chosen pilot product. Facilities typically produce a range of products and employ different unit operations to do so, and calculating the emissions for each product requires additional data above what is provided in the GHGRP and other data sets explored (e.g., public MECS data). One path forward is following a path similar to the EPA ENERGY STAR Energy Performance Indicator for Plants program, which has worked to create facility level distributions of energy intensities for several sectors[38]. Additional steps would be necessary to allocate emissions by product groups. Further, some facilities perform a subset of steps needed for a final material, buying semi-finished products or other intermediates, so steps would need to be taken to accurately account for all scopes 1 and 2 emissions from all facilities adding value to a given product.

[37] https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-iron-steel.pdf
[38] https://www.energystar.gov/industrial_plants/measure-track-and-benchmark/energy-star-energy

Additionally, coordination with and leveraging results from any USG ongoing effort towards determining manufacturing emissions at the product or facility level, such the EPA C-MORE program, would ensure consistency across USG methods and estimates.

It may also be feasible where certain data gaps exist to examine simple modeling approaches, for example to determine correlations between emissions and production for facilities with data and extrapolated to facilities without data. Corrections may need to be made to account for differences in emissions intensity for smaller facilities compared to larger facilities. These could reflect different levels of adoption of energy-efficient technologies. The results could be used to either estimate emissions intensities for non-reporting facilities for inclusion in the national facility-level estimate or to understand the magnitude of the share of unreported emissions. The latter would help to understand the representativeness of the estimated national facility-level emissions intensity if only reporting facilities were included.

Lastly, there is a need to better understand how well the available U.S. data can adequately and accurately represent each covered product in the product categories being considered, and to compare this to all major trading partners' data who would compete in the same markets.
It may be helpful to examine the level or groupings of HS product categories that could be evaluated using the GHGRP while still maintaining enough specificity to capture variation in emissions intensity.

Additional potential future work is outlined in the following.

Accessing and Using Census Microdata

In addition to the information from the GHGRP, the methodology described earlier describes the use of Census microdata that provides information on facility-level energy use and value of shipments. Access to this microdata is restricted to researchers with special sworn status working on active projects approved by the Census Bureau. For this reason, Census microdata was not available to the authors for testing the USG proposed method.

For these efforts, the MECS resource is a specific Census product of high interest. MECS gathers energy-related information from a statistically representative sample of U.S. facilities and rolls-up the results to provide estimates of U.S. manufacturing energy-related characteristics. The microdata for MECS is the root facility-level information gathered to produce the statistical rollup. MECS is currently conducted every four years[39], but has previously been collected more frequently[40]. MECS data can be cross-referenced to the AIES as well as to the Economic Census, conducted every five years (years ending in 2 and 7; the 2022 Economic Census data is in the midst of its release schedule, to conclude by March 2026), which provide information on facility output in monetary terms (e.g., value of shipments, inventories). While the

[39] At time of writing, the most recent MECS with public release was performed for 2018. The 2022 MECS is slated for release in 2025 so could be used for the next steps of this work.
[40] MECS was conducted every 3 years from 1985-1994; afterwards on a quadrennial basis https://www.census.gov/programs-surveys/mecs/about.html

primary production steel facilities appear to be well-represented in the GHGRP, other U.S. manufactured goods may not be as well represented as many facilities fall below the de minimis threshold for reporting (25,000 metric tons CO_2e/year for most sectors with some requiring all sectors to report). Given the MECS microdata is a sample across a sector, all facilities should be represented regardless of emissions thresholds thereby eliminating this issue.

In addition to determining scope 1 emissions at the facility-level for facilities not in the GHGRP, the micro MECS data could be used to obtain facility-level data for developing facility-level scope 2 emissions estimates, and applying more specific electricity grid (i.e., eGRID) emission factors. Additionally, and currently, the AIES also collects information on electricity purchases and the AIES microdata could be used for these purposes as well. The MECS sample frame can be studied, as well, to develop a sample frame for the purposes of determining a national average facility-level emissions intensity for traded goods, should a sampling approach be adopted.

Going forward, these are key data sources for gathering the distribution of energy intensity and related scope 1 and scope 2 emissions. These data sources will be at the 6-digit NAICS level, and its ability to provide facility-level emissions intensities at the 6-digit HS code level of products would need to be explored.

Testing With Additional Product Categories

The method outlined in this document will be tested using another economic product showing significant trade volumes in recent years. After a down-selection process that involved assessing trade data on highly traded U.S. sectors and products, the aluminum, cement, asphalt binder, glass, and chemicals sectors were chosen as potential test cases for future application of the USG proposed method. Further testing of the method would involve selecting a specific product from a single sector, e.g., ethylene in the chemicals sector, down to a granularity that is both consistent with the classification of goods in international trade and afforded by the data. The method will be tested by obtaining the required data to calculate scopes 1 and 2 emissions, output in physical units, and subsequently the national average facility-level emissions intensity of the chosen product.

Success or failure of the USG proposed method will be determined by the ability or a lack thereof to obtain required data at the prescribed level of detail and whether discrete sets of data retrieved for the product can be used consistently to calculate a facility-level emissions intensity value or range of values. Piloting the method with additional categories and richer data will further highlight existing data gaps that can inform priority areas for improving data monitoring, generation, and collection for emissions-intensive goods and sectors. This would also test for replicability for the USG to ultimately model similar national averages by product for other countries.

Technical Data Harmonization and Interoperability

Efforts to harmonize data across multiple sources will be required to ensure facility-level emissions intensity values are calculated across the same scope, timeframes and in the same units[41]. For example, this method relies on GHGRP data for scope 1 emissions, but also references the GHG Protocol and EPA's parameters for scopes 1 and 2 and refers to estimates from AIST. There are differences in each method and source. Some differences can be from system boundaries; for example steel production can include intermediate processing steps such as coke production or taconite induration.

Similarly, following the GHGRP enabling legislation[42], the U.S. reports emissions in CO_2e, including greenhouse gases such as N_2O and CH_4 in the scope. However, other countries may not include all GHGs in their determination of emissions. Further, reliance on MECS and other Census data products that are not issued yearly could mean a linkage of emissions data and production data from different years, which must be carefully tracked and accounted for to avoid error. Differences in the number of reporting facilities to different datasets (i.e., MECS used in scope 2 here includes significantly more facilities than GHGRP used in scope 1) create inconsistencies. Transparency in any assumptions used to harmonize data, as well as guidelines, will be necessary to ensure that the facility-level emissions intensity estimates are reliable and comparable.

Future work could also assess interoperability with the international trade system. This could include applying this methodology to estimate other countries' product-level national averages and reviewing calculation methodologies and data sources for traded products as currently used or proposed for use in trading partner jurisdictions (e.g. E.U., United Kingdom, Canada, Australia).

Conclusion

Developing consistent, accurate, and transparent national facility-level emissions intensities of traded U.S. products will be critical to support and expand current and future U.S. export industries that face GHG emission intensity-related measures in foreign markets. This assessment evaluated available USG datasets for estimating facility-level scope 1 and scope 2 emissions intensities for a pilot steel product using a method developed by the USG.

Publicly available U.S. government datasets serve as key analytical tools that deliver several benefits – including transparency and consistency over time. The U.S. benefits from having several such publicly available resources, such as the GHGRP, MECS, and eGRID databases. This study finds that for the test case of U.S. manufactured cold-rolled stainless steel with width

[41] Harmonization is used here in the technical sense; referring to allowing different data sets to be used together without distortion, see for example: https://www.industrialenergyaccelerator.org/wp-content/uploads/2404_IDDI-Guidance-for-PCR-Harmonisation_v1_0.pdf.
[42] https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98

less than 600 mm, there are constraints in the publicly available USG data when attempting to extend its use to determine facility-level emissions intensities.

This paper therefore identifies several challenges in developing final estimates and further refining the proposed method. For steel and other industries with a wide range of final products (i.e., more specific HS codes), determining specific product intensities will require more granular data downstream in the supply chain that reflects finishing energy and emissions intensities. Limiting analysis scopes to the closest product or HS code that the available data can accurately support can help overcome this challenge. Assessing and using non-public USG microdata, as proposed in the future work section, may also be more successful in supporting granular calculations.

Other industrial sectors and trade products may require new approaches, where data quality and availability may be different than the datasets discussed in this paper. The analysis boundaries may also need to be customized in future work to meet the needs of different trade policies and to account for allocation of facility-level emissions intensities between co-products produced at the same facility or one product produced at several facilities. These needs can be revisited and tailored to an analysis in future papers as needed.