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Greenhouse Gas Index for Products in 39 Industrial Sectors: Copper Ore

NAICS CODE 212230

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Working Paper 22-16 M24
September 2022

An Important Note

This module is not a stand-alone document. Readers should refer to the introduction for a more detailed overview and discussion of the Framework and procedures to determine the GGI and, especially, to the ***Note on Common References, Default Values, Acronyms and Abbreviations used in the Modules***. Common information includes default values for CO_2 emissions from electricity and thermal energy derived from coal, oil and natural gas; a list of acronyms and abbreviations; guidance on using the sources cited for US exports, imports, and production by sector, and CO_2 emissions from electricity produced in nations that export to the United States.

Sharing Our Work

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1. Introduction

This NAICS code includes establishments engaged in mining various ores, including copper (Cu). The establishments use energy to mine their ore. During 2019, US exports of copper ores and concentrates totaled $2.28 billion; US imports were $153 million.[1] The total production of copper ore in the United States in 2019 was 1.3 million short tons, with a value of about $7.9 billion.[2] Under the Framework we've proposed, rebates and import charges would be based on an upstream US GHG tax and the greenhouse gas indices (GGIs) for the imported and exported products.[3] The estimated GGI for concentrated ore (assuming the copper concentration is 35 percent) ranges from 2.14 tonnes CO_2e/tonne Cu concentrate from underground mining using electricity derived from coal to 0.42 tonnes CO_2e/tonne Cu concentrate from open pit mining using electricity derived from natural gas.

In this module, we determine GGIs—which track taxed sources of GHG emissions from operations of the establishment and those along the supply chain to produce GHG-intensive products purchased from suppliers in a manner analogous to that used in value-added taxes—for copper ore. As described in the Framework report, the GGI provides the basis to determine border tax adjustments (BTAs—export rebates and import charges). When the GGI is multiplied by the GHG tax, the result is the relevant export rebate and import charge.

A minimum threshold GGI of 0.50 tonnes CO_2e/tonne product is required for an export rebate or the imposition of an import charge. We refer to such covered products as GHG-intensive products. More than one estimate for the GGIs of copper concentrate are less than the minimum threshold, while several are equal to or greater than the threshold. Thus, there is a strong possibility that some of the products from facilities in this sector will have GGIs of less than 0.50 tonnes CO_2e/tonne concentrate and thus not be eligible for an export rebate or have an import charge imposed.

As described in the introduction to the modules, there are two major steps involved in determining GGI values for these products. The first is to evaluate the total input of taxed sources of GHG emissions—$CO_2e(TOT)$. The second is to allocate this total to the entire slate of covered products created by the manufacturer. For this sector, we describe processes that each make a single covered product (P)—in this case, copper ore. Determination of the GGI for copper ore is based on

[1] *See*: **https://usatrade.census.gov/data/Perspective60/View/dispview.aspx.**

[2] *See*: Sheet, **https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-copper.pdf.**

[3] *See*: Flannery, Brian, Jennifer A. Hillman, Jan Mares, and Matthew C. Porterfield. 2020. *Framework Proposal for a US Upstream GHG Tax with WTO-Compliant Border Adjustments: 2020 Update*. Washington, DC: Resources for the Future. **https://www.rff.org/publications/reports/framework-proposal-us-upstream-ghg-tax-wto-compliant-border-adjustments-2020-update/**

allocating the total taxed sources of CO_2e emissions required to produce the total amount of product based on weight:

$CO_2e(TOT)$ = total taxed sources of GHG emissions (tonnes CO_2e);
$M(P)$ = total mass of copper concentrate products (tonnes of Cu concentrate);
GGI = $CO_2e(TOT)/M(P)$ (tonnes CO_2e/tonne Cu concentrate).

This module provides a means for the Regulator to estimate, based on public information, initial export rebates for US exporters and charges for US imports of GHG-intensive and/or trade-exposed products if there were an upstream GHG tax of $20 per tonne of CO_2. This information would be useful to the Regulator in evaluating the information provided by exporters to indicate their requested export rebate.

The estimates in this module are based on publicly available information. Miners of copper ore and producers of concentrate to be smelted by the pyrometallurgical process will know the amount of electricity and fuel consumed in producing such products and can obtain the GGI of each from their suppliers. Related information to determine rebates and import charges could undoubtedly be obtained by the Regulator from either the domestic industry or firms (like CRU Group) which have a business of obtaining and marketing information about the GHG aspects of various products.

The major participants of the US copper mining and concentrating industry are already obligated annually to determine and report to the US Environmental Protection Agency (EPA) their facility GHG emissions if they are over 25,000 tonnes per year. They will also know the amounts and types of covered products they manufacture, and, under the Framework in the United States, suppliers would be obligated to inform customers (and the Regulator) of the GGI values of the GHG-intensive products that they sell. Therefore, manufacturers have the information needed to determine the GGI values for GHG-intensive products they create in specific facilities. For a given firm, an average GGI for each product will be evaluated based on production of each such product from all its domestic facilities as the basis to request a rebate. For import charges, the average GHG emissions from fuels used to manufacture electricity in the relevant country should be used to determine the CO_2 emissions from electricity use associated with the production of copper ore unless and until more specific, verifiable information for the nation as a whole or for electricity use by individual firms is provided to the Regulator. Such national average electricity information can be found in reports from the International Energy Agency (IEA).[4]

An important note: We emphasize that the estimates in this module are meant to provide only indicative, representative values for the GGIs of US copper ore products. Some of the public data that the calculations rely on probably are not representative

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[4] See: IEA's *World Energy Balances 2020*, **https://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics.**

of industry performance today. Actual values will depend on determination of the GGI for each specific product produced at a specific facility. Since companies, associations, and commercial firms that collect and market information about the energy and emissions profiles of various products can provide more accurate information than was used here, the Regulator should seek such information when determining potential import charges or evaluating requests for export rebates. The estimates here do not account for all chemicals or other raw materials that may have incurred the GHG tax directly or indirectly. Subject to the administrative costs to evaluate all such inputs and be consistent for both export rebates and import charges, the Regulator should strive to accept all verifiable raw material inputs to the GGI for specific products.

2. Copper Ore

Copper ore is predominantly mined in open pits and generally has less than 1 percent copper.[5] It is ground and concentrated in a beneficiation process that first involves crushing and grinding the ore. Then, it is concentrated in a froth flotation process to separate the pulverized ore from the non-valuable portions of the ore. This process and mining represent over half of the energy required to produce copper cathodes or billets. The separated ore is usually sent elsewhere to be smelted, converted, or electro-refined by either pyrometallurgical processes or hydrometallurgical processing. We assume in this analysis that the copper percentage in concentrate is about 35 percent.

Estimates exist of the energy used to mine and process copper ore to a concentrate, and several published studies outline the energy used to mine copper ore and create copper.[6] Firms seeking an export rebate or subject to an import charge should provide the Regulator with the ore grade as well as the GGI for the concentrated ore that they seek to export or import. We consider two cases: production of underground ore and open-pit mining of ore. In each case, we consider electricity produced from natural gas or from coal.

2.1. Underground Mining and Concentrating Copper Ore

According to Table A2 of the Rötzer and Schmidt paper (see footnote 6), if the concentrated ore was derived in 2010 from a 0.7 percent ore body, the contributions to CO_2e(TOT) would be as follows:

2.1.1. For Underground Mining

- Electricity: (25 kWh/tonne ore) (1 tonne ore/0.007 tonnes Cu) = 3,575 kWh/tonne Cu.
  From natural gas: (3,575 kWh/tonne Cu) (0.42 tonnes CO_2e/1,000 kWh) = 1.50 tonnes CO_2e/tonne Cu.
  From coal: (3,575 kWh/tonne Cu) (1.0 tonnes CO_2e/1,000 kWh) = 3.58 tonnes CO_2e/tonne Cu

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[5] See: **https://www.copper.org/education/copper-production/2.html#:%7E:text=Open%20pit%20mining%20is%20the%20most%20widely%20used,copper%20ore%20is%20not%20near%20the%20earth%27s%20surface**; and **https://investingnews.com/daily/resource-investing/base-metals-investing/copper-investing/types-copper-deposits-world/**

[6] *See:* Rötzer, N., and M. Schmidt. 2020. "Historical, Current, and Future Energy Demand from Global Copper Production and Its Impact on Climate Change." *Resources* 9(4). **https://doi.org/10.3390/resources9040044**; and Marsden, J. 2008. "Energy Efficiency & Copper Hydrometallurgy." **https://www.researchgate.net/publication/265156153_Energy_Efficiency_Copper_Hydrometallurgy**.

- Diesel: (2,460 MJ diesel/tonne Cu) (948 Btu/MJ) (0.0733 tonnes CO_2e/MBtu) = 0.171 tonnes CO_2e/tonne Cu.

The contribution to CO_2e(TOT) from diesel fuel and electricity used in mining would be 1.67 tonnes CO_2e/tonne Cu with electricity based on gas, or 3.75 tonnes CO_2e/tonne Cu with electricity based on coal.

2.1.2. From Processing, Assuming Ore is 0.7 Percent Cu

- Electricity: (16.4 kWh/tonne ore milled) (143 tonnes ore/tonne Cu) = 2,345 kWh/tonne Cu
  From natural gas: (2,345 kWh/tonne Cu) (0.42 tonnes CO_2e/1,000 kWh) = 0.985 tonnes CO_2e/tonne Cu
  From coal: (2,345 kWh/tonne Cu) (1 tonne CO_2e/1,000 kWh) = 2.35 tonnes CO_2e/tonne Cu

Combining the results for underground mining and processing of ore using diesel fuel and electricity from electricity or coal results in GGI values as follows:

GGI	=	CO_2e(TOT)/tonne Cu;
	=	(1.67 + 0.985) tonnes CO_2e/tonne Cu
GGI	=	2.66 tonnes CO_2e/tonne Cu, based on natural gas for electricity.

GGI	=	CO_2e(TOT)/tonne Cu;
	=	(3.75 + 2.35) tonnes CO_2e/tonne Cu
GGI	=	6.10 tonnes CO_2e/tonne Cu, based on coal for electricity.

At 35 percent copper concentration, the corresponding GGI values per tonne of processed ore would be as follows:

GGI	=	0.93 tonnes CO_2e/tonne Cu concentrate, based on natural gas for electricity; and
GGI	=	2.14 tonnes CO_2e/tonne Cu concentrate, based on coal for electricity.

Note that if the Cu content of the concentrate is about 18 percent or less, the GGI for such concentrate mined and processed using gas for electricity will be less than 0.50 and in such case will not be entitled to a rebate nor would it warrant an import charge.

2.2. Open-Pit Mining and Concentrating Copper Ore

For open-pit ore using data from Table A2 of the Rötzer and Schmidt paper (see footnote 6), the contributions to CO_2e(TOT) would be as follows:

2.2.1. From Mining

- Electricity: (1 kWh/tonne ore) (1 tonne ore/0.007 tonne Cu) = 143 kWh/tonne Cu.

From natural gas: (143 kWh/tonne Cu) (0.42 tonnes CO_2e/1,000 kWh) = 0.060 tonnes CO_2e/tonne Cu.
From coal: (143 kWh/tonne Cu) (1.0 tonne CO_2e/1,000 kWh) = 0.143 tonnes CO_2e/tonne Cu

- Diesel: (2,243 MJ diesel/tonne Cu) (948 Btu/MJ) (0.0733 tonnes CO_2e/MBtu) = 0.156 tonnes CO_2e/tonne Cu.

The contribution to CO_2e(TOT) from diesel fuel and electricity would be 0.216 tonnes CO_2e/tonne Cu with electricity based on gas, or 0.299 tonnes CO_2e/tonne Cu with electricity based on coal.

2.2.2. From Processing, Assuming Ore is 0.7 Percent Cu

- Electricity: (16.4 kWh/tonne ore milled) (143 tonnes ore/tonne Cu) = 2,345 kWh/tonne Cu
  From natural gas: (2,345 kWh/tonne Cu) (0.42 tonnes CO_2e/1,000 kWh) = 0.985 tonnes CO_2e/tonne Cu.
  From coal: (2,345 kWh/tonne Cu) (1 tonne CO_2e/1,000 kWh) = 2.35 tonnes CO_2e/tonne Cu.

Combining the results for open-pit mining and processing of ore using diesel fuel and electricity from natural gas or coal results in GGI values as follows:

GGI = CO_2e(TOT)/tonne Cu;
= (0.216 + 0.985) tonnes CO_2e/tonne Cu
GGI = 1.20 tonnes CO_2e/tonne Cu, based on natural gas for electricity.

GGI = CO_2e(TOT)/tonne Cu;
= (0.299 + 2.35) tonnes CO_2e/tonne Cu
GGI = 2.65 tonnes CO_2e/tonne Cu, based on coal for electricity.

At 35 percent copper concentration, the corresponding GGI values per tonne of processed ore would be as follows:

GGI = 0.42 tonnes CO_2e/tonne Cu concentrate, based on natural gas for electricity; and
GGI = 0.93 tonnes CO_2e/tonne Cu concentrate, based on coal for electricity.

Note that for 35 percent Cu concentrate with open pit mining and processing using diesel fuel and electricity based on natural gas, the GGI—0.42 tonnes CO_2e/tonne Cu concentrate—would be below the minimum threshold of 0.50 tonnes CO_2e/tonne Cu concentrate and so would not be eligible for a rebate or subject to an import charge.

The GGIs for copper ore concentrate with 35 percent Cu content mined and processed based on natural gas or coal for electricity and assuming diesel fuel is used in mining are as follows:

Table 1. GGI by Source and Electricity Type

Source	Electricity	GGI (t CO_2e/t Cu concentrate)
Underground	Gas	0.93
	Coal	2.14
Open Pit	Gas	0.42
	Coal	0.93

3. Export Rebates

Under Harmonized Tariff Schedule (HTS) Code 26030010 (for copper ores and concentrates), exporters of copper ore and concentrate reported $2.28 billion exports in 2019. Based on the GGIs developed above, the anticipated rebate for these products—if there were a GHG tax of $20 per tonne of CO_2—would be as follows, depending on the process and type of energy used:

Table 2. Export Rebate by Source and Electricity Type

Source	Electricity	GGI (t CO_2e/t Cu concentrate)	Rebate ($/tonne)
Underground	Gas	0.93	18.60
	Coal	2.14	42.80
Open Pit	Gas	0.42	0.00
	Coal	0.93	18.60

4. Import Charges

In 2019, there were about $153 million worth of copper ores and concentrates (included in HTS Code 26030010) imported into the United States. The GGIs and import charges for these products should initially be the same as provided above for export charges until exporters to the United States provide the Regulator with verifiable information about the GGI of such imports, the mining and production processes used, the concentration of copper in ore or concentrate, and the GGI for the electricity used to manufacture such imports.