RESOURCES *for the* FUTURE

Greenhouse Gas Index for Products in 39 Industrial Sectors: Petroleum Refinery Products

NAICS CODE 324110

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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

Contents

1. Introduction

The NAICS Code 324110 (petroleum refinery products) consists primarily of 11 products. The products covered in this module include motor gasoline, diesel, aviation gasoline, kerosene-type jet fuel, kerosene, naphtha, distillate fuel oil, residual fuel oil, lubricants, waxes, and petroleum coke According to US Trade Online data on petroleum refinery products for 2018, the value of US exports of these products was about $103 billion, and the value of US imports was about $66 billion. In 2018, total production amounted to about $625 billion.[1] Under the Framework we've proposed, export rebates and import charges would be based on an upstream US greenhouse gas (GHG) tax and the GHG indices (GGIs) for the imported and exported products.[2]

In this module, we determine indicative, representative GGIs—which track GHG process emissions and the contribution of the carbon content of products derived from fossil resources along the production and supply chain in a manner analogous to that used in value-added taxes—for such petroleum refinery products. When multiplied by the GHG tax, the result is the relevant export rebate and import charge, provided it is equal or greater than 0.50 tonnes CO_2e/tonne refined product. We refer to products that meet this threshold as GHG-intensive products. The GGIs for such petroleum refinery products range from from 3.59 tonnes CO2e/tonne aviation gasoline to 3.88 tonnes CO2e/tonne petroleum coke, to 4.04 tonnes CO_2e/tonne waxes. Typical liquid fuels, such as gasoline and diesel, have GGI values of approximately 3.65 tonnes CO_2e/tonne product.

Because refineries do not produce in-ground fossil resources and have few, if any, GHG process emissions, refineries would pay little or no GHG tax if there were an upstream GHG tax. Consequently, contributions to the GGIs from the GHG-intense products of refineries come entirely from the GGI values associated with GHG-intense products purchased from suppliers—primarily crude oil, commercial fuels, and electricity. In some cases, refineries may purchase other GHG-intense products (e.g., hydrogen) used in separations and chemical processing. Note also that many refineries utilize cogeneration of steam and electricity (see Section 4.2 of the Framework) that are not specifically accounted for in our estimates based on national averages.

As described in the Framework and summarized in the introduction to these modules, there are two major steps involved in determining GGI values for refined products. The first is to evaluate the total input of taxed sources of GHG emissions—CO_2e(TOT). For

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[1] **https://usatrade.census.gov/data/Perspective60/Dim/dimension.aspx?ReportId=38**); **https://data.census.gov/cedsci/table?q=AM1831BASIC&n=N0600.00**.

[2] 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/**

refined products, determination of $CO_2e(TOT)$ is simplified because there are no fossil resources produced in the manufacturing process itself and operations to produce refined products generate no GHG emissions from untaxed sources. Contributions to $CO_2e(TOT)$ therefore occur only from purchased GHG-intensive feedstocks. The second is to allocate this total to the entire slate of covered products created by the manufacturer. Since products are derived from produced fossil resources, we propose that allocation of total emissions to these products should be based on the fraction of carbon by weight in each product—*cf*.

Allocation by carbon content is based on first determining the average CO_2e emissions per tonne of carbon C, $<CO_2e/C>$,[3] in all products, and then allocating GHG emissions to products based on *cf*. As described in the introduction to the modules, $<CO_2e/C> = <CO_2e(TOT)/M(C)>$, where M(C) is the mass of carbon in all covered products. The manufacturer will know the composition and amounts of covered products they produce. So, for each refined product,

$$GGI = <CO_2e/C> \, cf.$$

In the United States, petroleum refineries are already obligated annually to determine and report to the US Environmental Protection Agency (EPA) their GHG emissions from facilities that emit over 25,000 tonnes of CO_2e per year. They will also know the amounts and types of covered products they manufacture, and, under the Framework in the United States, suppliers of GHG-intensive covered products would be obligated to inform customers (and the Regulator) of the GGI values of 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.

In a refinery, crude oil is processed by its distillation into various products—which are separated, cracked, and combined to make the ultimate refinery products. Note that the amount of carbon contained in all final products may be more or less than the amount of carbon flowing into the refinery in crude oil—depending on possible sources of carbon in other purchased products as well as the combustion of some of the embedded carbon in crude and commercial fuels to produce energy in the refinery. Here we rely on simplifying assumptions to determine representative, indicative estimates of GGI values for refinery products.

As described in an accompanying module on crude petroleum and natural gas, factors contributing to the GGI of crude oil vary significantly depending on the geological circumstances, properties of the in-ground oil resource, and technologies used to produce the oil. Within the refinery, energy use and GHG emissions occur from many sources. Major sources include heat (used for distillation and to produce steam); the combustion of portions of the crude oil to regenerate catalysts and for process heat;

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[3] See the discussion in the introduction concerning the use of angle brackets "< >"to denote an average over the entire operation, e.g., a facility or entire sector, in this case to produce refined products.

electricity used to control process units; and the use of purchased products and refinery process streams to upgrade to cleaner and higher-value products. Section 4.2 of the Framework (see footnote 2) describes our proposed treatment of cogeneration of steam and electricity—an important, energy-saving process that that is utilized in some refineries.

This module provides a means for the Regulator to estimate, based on public information, initial export rebates and import charges of refined petroleum products if there were an upstream US GHG tax of $20 per tonne of CO2 that provided for such rebates and charges. This information would be useful to the Regulator in evaluating the information provided by exporters to indicate their requested export rebate and in establishing initial import charges.

An important note: We emphasize that the estimates in this module are meant only to provide indicative, representative values for the GGIs of US refined products. Actual values will depend on the 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 a product 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. Refined Products

Our indicative estimates for taxed sources of GHG emissions that contribute to the GGIs of products from refineries include contributions from the extraction and initial processing of in-ground oil resources to produce crude oil as well as from processing the crude oil in refineries. The dominant contribution to the GGIs occurs from embedded carbon in feedstocks, electricity, and fuels, most of which derives from the embedded carbon in crude oil. We allocate total contributions to all products of the refinery based on their carbon content by weight, GGI = <CO_2e/C> *cf*, as described above.

The module on crude petroleum and natural gas extraction indicates that the average GGI for crude oil produced in the United States is estimated to be 3.27 tonnes CO_2e/tonne oil. However, as described below, US refineries process a significant amount of imported oil.

To evaluate GHG emissions from processing crude oil in refineries, we use national averages from 2015 for the total amount of crude oil processed in US refineries, GHG emissions from fuels used in refineries, and for amounts processed. We derive estimates of GHG emissions and/or fuel used from data from EPA and the US Energy Information Administration (EIA).[4] Total emissions from fuel used amounted to 175 million tonnes CO_2e, equivalent to the combustion of 47.7 million tonnes of carbon. In that year, according to EIA, US refineries processed approximately 16.2 million barrels (BBL)/day. There are approximately 7.4 BBLs per tonne of crude oil (see footnote 9) with a typical carbon fraction 85 percent by weight,[5] so this corresponds to 799 million tonnes of crude oil or 679 million tonnes of carbon. Consequently, on average, GHG emissions associated with refining crude oil amounted to approximately 7 percent relative to emissions from burning 100 percent of the embedded carbon.

In summary, based on the estimates above for US production and refining of US crude oil (compared with CO_2e emissions resulting from burning 100 percent of the carbon embedded in crude oil), CO_2e emissions from operations to extract and process in-ground oil to produce crude oil add approximately an additional 4 percent to emissions (at least), and those from producing products in a refinery add about another 7 percent. However, note that oil producers in the United States export a significant fraction of the crude oil they produce, and a significant fraction of crude oil refined in the United States is imported.

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[4] *See:* Table 4 of 2011-2017 GHGRP Industrial Profile, Petroleum Refineries, **Greenhouse Gas Reporting Program Industrial Profile: Petroleum Refineries Sector (epa.gov)**; Refinery Net Input, **US Refinery Net Input (eia.gov)**.

[5] **https://www.britannica.com/science/crude-oil#:~:text=Regardless%20of%20variations%2C%20however%2C%20almost%20all%20crude%20oil,most%20prevalent%20in%20them%3A%20paraffins%2C%20naphthenes%2C%20and%20aromatics**.

Using different methodologies, other recent sources[6,7] indicate that, on a global basis, GHG emissions associated with crude oil production are closer to 5–6 percent relative to the carbon content alone of produced crude oil. An earlier 2014 analysis[8] based on a US average from a life-cycle assessment of GHG emissions indicated that total GHG emissions from production and refining of crude oil to produce gasoline were about 20 percent relative to full well-to-wheels emissions. These analyses provide typical values for overall average estimates of emissions required to determine GGIs. In practice, they would need to be determined based on information for specific operations and facilities.

Given these studies and estimates, for this module we adopt as indicative, representative values for overall GGIs of refined products that the total taxed sources of GHG emissions, $CO_2e(TOT)$, will be approximately 15 percent greater than would be estimated based on only the embedded carbon content of refined products—i.e., $CO_2e(TOT) = (44 \text{ tonnes } CO_2/12 \text{ tonnes C})\ (1.15)\ M(C) = 4.217\ M(C)$, where M(C) is the total amount of carbon by weight in products. Of these additional contributions to the GGI, approximately two-thirds (10 percent) result from refinery operations and approximately one third (5 percent) results from the production of crude oil. Thus, for refined products, the GGI is calculated as follows:

$$\langle CO_2e/C \rangle = CO_2e(TOT)/M(C) = 4.22 \text{ tonnes } CO_2e/\text{tonne C};$$

$$GGI = \langle CO_2e/C \rangle\ cf;$$

$$GGI = 4.22\ cf \text{ tonnes } CO_2e/\text{tonne product.}$$

From the above discussions, these adopted estimates may be conservative (i.e., actual emissions that contribute to GGIs may be on average a few percent larger). In any event, actual emissions from producing fields and refineries may differ by several percent from those adopted for estimates in this module.

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[6] Masanadi, M.S., et al. 2018. Global Carbon Intensity of Crude Oil Production. *Science* 361(6405): 851–853. **https://www.science.org/doi/10.1126/science.aar6859**

[7] *See*: Oil and Gas Climate Initiative: Upstream Carbon Intensity Target (2020); **https://oilandgasclimateinitiative.com/action-and-engagement/reducing-carbon-dioxide-emissions/#carbon-target.**

[8] Lattanzio, Richard K. 2014. Canadian Oil Sands: Life-Cycle Assessments of Greenhouse Gas. Congressional Research Service (see Figure 3). **https://fas.org/sgp/crs/misc/R42537.pdf**

3. Export Rebates

The following table provides estimates for the GGIs of refinery products and for export rebates based on multiplying their GGIs by the assumed US GHG tax rate of $20 per tonne of CO_2. Results in columns 2 and 3 were determined using information reported by the International Energy Agency (IEA)[9] (barrels per tonne of petroleum product) and the US EIA[10] (CO_2 emissions per gallon of product, P). Note that liquid fuels and related petroleum products are quantified by volume, not mass (e.g., gallons or liters, not pounds or kilograms). So, values for emissions and densities of products can readily vary by a few percent or more among different producers processing different crude oils, and product information need not be consistent across the IEA and EPA reports. There simply is no universal standard, for example, for *cf* or CO_2 emissions per tonne of product. So, the use of figures listed to three decimals should not be taken as definitive.

Table 1. Products of US refineries: Carbon content, GGIs, and export rebates

Refinery Product	**Carbon Fraction *cf***	**CO2**	**GGI†**	**Export Rebate‡**
P	tonnes C/ tonne P	tonnes CO_2/ tonne P	tonnes CO_2e/ tonne P	US$/tonne P
Finished motor gasoline	0.863	3.16	3.64	$72.78
Diesel[11]	0.863	3.16	3.64	$72.78
Finished aviation gas	0.852	3.12	3.59	$71.80
Kerosene-type jet fuel	0.859	3.15	3.62	$72.44
Kerosene	0.868	3.18	3.66	$73.20
Distillate fuel oil	0.868	3.18	3.66	$73.20
Residual fuel oil	0.899	3.30	3.79	$75.80
Naphtha	0.868	3.18	3.66	$73.20
Lubricants	0.865	3.17	3.65	$73.00
Waxes	0.958	3.51	4.04	$80.80
Petroleum coke	0.919	3.37	3.88	$77.60

† Contributions from taxed sources of GHG (CO_2e) emissions from crude oil, electricity, and other GHG-intensive products used by refineries add approximately 15% to the total from embedded carbon in refined products.
‡ Export rebate evaluated for an assumed GHG tax of $20 per tonne of CO_2.

[9] **https://iea.blob.core.windows.net/assets/97bc371b-cf81-4694-a84d-46ac4f0e6b4a/Oil_documentation-2020.pdf. See page 66, Oil Products Average Densities BBL/Tonne.**
[10] **https://www.eia.gov/environment/emissions/co2_vol_mass.php.**
[11] While diesel fuel is denser than gasoline, their carbon fractions by weight are nearly identical See: **https://iea-amf.com/content/fuel_information/diesel_gasoline**.

4. Imports and Import Charges

A significant number of refined products are imported into the United States. They are made in an even more diverse group of refineries than exist in the United States. Commercial firms with data can provide information about countries and/or refineries that can be used to estimate GGIs for imports of refined products. Relevant information is also available from a variety of sources as described in the Framework (see footnote 2), including from many nations that already require GHG reporting from facilities of energy-intensive, trade-exposed sectors and other GHG-intensive sectors. We recommend that information on the GGIs of GHG-intensive products imported from other nations should be reported by firms that import covered products into the United States within two years after the program commences.

Until importers provide the Regulator with credible, verifiable information to support and claim a lower GGI value for their refined products, the Regulator could use the GGIs estimated here for such imports (as estimated based on US refined products). In creating estimates for the GGIs of imported products, it will be important to determine or estimate all sources of GHG emissions in the producing country that would be taxed in the United States in the course of producing and refining crude oil (e.g., those from GHG process emissions, especially venting and flaring of associated gas, and those associated with purchased products, especially electricity and commercial fuels). Such emissions can vary widely across producers and refiners. GHG emissions from production and refining of Canadian oil from oil sands are on average about twice those from conventional US sources (see footnote 8), though they vary considerably depending on the specific resources and technology used to extract and process oil sands. That information would enable the Regulator to base those respective import charges on more specific, appropriate data to determine their GGIs.

If there were an upstream GHG tax of $20 per tonne of CO_2 and the import charge was based on the US GGI for the particular product as estimated above, the import charge would be the same for that product as the export rebate for the same domestically produced product. Thus, the table above for export rebates provides estimates of what would be import charges for various products. In practice, GGI values for imported refined products may differ significantly from those based on crude oil produced and refined in the United States.