RESOURCES
for the FUTURE

Greenhouse Gas Index for Products in 39 Industrial Sectors: Crude Petroleum and Natural Gas Extractions

NAICS CODES 211120 AND 211130

Brian P. Flannery and Jan W. Mares

Working Paper 22-16
September 2022

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

Establishments covered under NAICS Codes 211120 and 211130 are primarily engaged in producing oil and natural gas. Operations to produce oil and natural gas use greenhouse gas (GHG)-intensive energy and emit methane and other GHGs as process emissions. During 2018, the import values in the United States of crude petroleum and natural gas were about $162 billion and $11 billion, respectively.[1,2] Exports of oil were $65 billion; exports of natural gas, excluding liquified natural gas (LNG), were $8.4 billion. The total production of oil in the United States in 2019 was 12.2 million barrels (BBLs) per day—with a value of $223 billion at $50 per BBL or $178 billion at $40 per BBL. At the same time, natural gas production was 40.7 trillion cubic feet—which at $2.75 per kscf (1,000 standard cubic feet) wellhead price had a value of $112 billion. 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]

In this module, we determine 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 produced oil and natural gas products. When multiplied by the GHG tax, the result is the relevant export rebate or import charge. A minimum 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 products that meet this threshold as GHG-intensive products. The GGI for oil is estimated to be 3.27 tonnes CO_2e/tonne oil. The GGI for natural gas is estimated to be 3.06 tonnes CO_2e/tonne gas.

As described in the introduction to the modules, there are two major steps involved in determining GGI values for the production of in-ground oil and natural gas resources. 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

[1] For information on petroleum: **https://www.eia.gov/petroleum/supply/annual/volume1/**.
[2] For information on natural gas: **https://www.eia.gov/naturalgas/annual/pdf/table_001.pdf,** and for further detail:
https://www.eia.gov/dnav/ng/ng_move_expc_s1_a.htm;
https://www.eia.gov/todayinenergy/detail.php?id=43115;
https://www.eia.gov/todayinenergy/detail.php?id=42337#:~:text=As%20natural%20gas%20production%20increased,%25%20to%203.0%20Bcf%2Fd.
https://www.eia.gov/todayinenergy/detail.php?id=43015#:~:text=U.S.%20crude%20oil%20production%20grew,12%20million%20barrels%20per%20day&text=Annual%20U.S.%20crude%20oil%20production,17%25%20growth%20rate%20in%202018.
https://usatrade.census.gov/data/Perspective60/View/dispview.aspx.
[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/

created by the producer. Three sources contribute to $CO_2e(TOT)$ in this module: 1) the carbon content of products from the produced fossil resource; 2) GHG process emissions released during production (e.g., venting and flaring of natural gas, and, in some cases, use of some of the produced resource as fuel to generate thermal energy and/or steam); and 3) the use of GHG-intensive products purchased from suppliers, especially electricity and fuels.

For produced fossil resources, allocation by carbon content is based on determining the average taxed sources of CO_2e emissions per tonne of carbon (C) in all products: $<CO_2e/C> = CO_2e(TOT)/M(C)$, where M(C) is the total mass of carbon in all covered products,[4] and then allocating taxed sources of GHG emissions to products based on *cf* (the fraction of carbon by weight in each product). For each product, GGI = $<CO_2e(TOT)/C>$ *cf*. In this module we focus on the dominant, major products of oil and gas producers (namely crude oil and processed natural gas), without considering other products, such as associated gas and liquid condensate. Note that in the event that the manufacturer produces only a single covered product, P, GGI = $CO_2e(TOT)/M(P)$, where M(P) is the weight of the covered product (tonnes P). Allocation only requires specific, product-by-product determination when the manufacturer creates more than one covered product in the process being considered.

This module illustrates how, using available public information, to determine GGI(crude oil) = $CO_2e(TOT)$/tonne of crude oil; and GGI(natural gas) = $CO_2e(TOT)$/tonne of natural gas. In practice, GGI values will vary for different production operations depending on the geology of the in-ground natural resource, its chemical and physical properties, and the processes used to extract and initially process crude oil and natural gas.

This module provides a means for the Regulator to estimate, based on public information, initial export rebates for US exporters and import charges for imports to the United States of crude petroleum and natural gas—if there were an upstream GHG tax that provided for such rebates and import charges. This module uses such information to indicate what such export rebates and import charges would be 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.

Producers of oil and natural gas with facilities releasing 25,000 tonnes or more of GHG emissions per year are already obligated to determine and report their GHG emissions from development and production operations. Some of this information is available in the US Environmental Protection Agency’s (EPA’s) yearly Inventory of US Greenhouse

---

[4] 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 crude petroleum or natural gas.

Gas Emissions and Sinks.[5] Producers will know the composition and amounts of covered products they produce, and under the proposed Framework, suppliers would communicate GGI values for their covered products to their customers (and the Regulator). So, producers will have the information they need to determine GGI values for their products. More accurate and timely information to determine rebates and import charges could undoubtedly be obtained by the Regulator from either the industry association or firms (such as from S&P Global, which has a business of obtaining and marketing information about the GHG aspects of various products).

An important note: We emphasize that the estimates in this module are meant to provide only indicative, representative values for the GGI of US oil and gas products. Some of the public data that the calculations rely on probably are not representative of industry performance today. Actual values will depend on the determination of the GGI for each specific product created at a specific facility. Since companies, associations, and commercial firms that collect and market information about products' energy and emissions profiles 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 GHG-intensive chemicals or other raw materials that may contribute to the GGI. 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 of specific facilities.

[5] *See:* **https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks 2020**.

2. Petroleum

Our representative, indicative estimates for taxed sources of GHG emissions that contribute to the GGI for petroleum include contributions from GHG-intensive products purchased in their supply chain, as well as sources for which operators will pay the GHG tax, namely, the carbon content of produced resources and GHG emissions that occur during the extraction and initial processing of in-ground oil resources to produce crude oil and associated products. The dominant contribution to the GGI occurs from embedded carbon in the petroleum, which varies depending on the type and source of the petroleum.

Although the carbon content of crude oil varies, as a representative value for these estimates we assume 85 percent carbon by weight. For an estimate of GHG emissions from production and initial processing of crude oil in the United States, we use data from EPA's Inventory of US Greenhouse Gas Emissions and Sinks (1990–2018; see footnote 5), which indicates (at page 3-69) that total GHG emissions from crude oil production (excluding engine combustion, of which much occurs in exploration and production) were 68.5 million tonnes of CO_2e in 2018. Also, in 2018, the US Energy Information Administration (EIA) reported 10.94 million BBL/day of domestic crude oil production,[6] which (at 7.46 BBL per tonne of domestic crude oil)[7] corresponds to 541 million tonnes of produced crude oil. Thus, GHG process emissions and emissions associated with oil production (excluding engine combustion) amount to 0.126 tonnes CO_2e/tonne crude on average. Assuming that 100 percent of the carbon in crude oil will ultimately be combusted to emit CO_2, on average this would produce 3.667 tonnes CO_2/tonne carbon or 3.116 tonnes CO_2/tonne crude oil from its carbon content. So, on average, the total contributions to CO_2e (TOT) of crude oil production in the United States would be approximately 3.24 tonnes CO_2e/tonne crude oil. This is approximately 4 percent larger than would be estimated based on embedded carbon alone. Note that contributions to the GGI would also include emissions of CO_2 from the combustion of purchased fuels and, in some cases, portions of the produced oil that are not tallied in EPA's inventory cited above. Consequently, the GGI would be somewhat larger.

Using different methodologies, other recent sources indicate that, on a global basis, GHG emissions associated with crude oil production on average are closer to 5–6 percent larger than from the carbon content alone.[8,9] Additionally, a 2014 analysis

---

[6] **https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrfpus2&f=a**)

[7] **https://www.ipaa.org/reference-tools/#:~:text=One%20metric%20ton%20of%20crude,barrels%20of%20domestic%20crude%20oil**

[8] *See*: Masanadi et al. 2018. "**Global carbon intensity of crude oil production**." *Science* 361(6405:) 851–853.

[9] *See:* Oil and Gas Climate Initiative. 2020. **Upstream carbon intensity target**. **https://oilandgasclimateinitiative.com/action-and-engagement/reducing-carbon-dioxide-emissions/#carbon-target**

based on a US average from life-cycle assessments of GHG emissions in 2005 indicates that total GHG emissions from production and refining of crude oil to produce gasoline were roughly 20 percent greater than those calculated solely on the carbon content of the fuel (with roughly one-third from production and two-thirds from refining). [10] These analyses provide typical values for overall average estimates of emissions required to evaluate the GGI. In practice, they would need to be evaluated based on the actual practices of specific operations and facilities.

Given these studies and estimates, for this module we adopt as indicative, representative values of the overall GGI of crude oil to be approximately 5 percent greater than would be estimated based on only the embedded carbon content of the crude oil. Thus, we estimate the GGI for crude oil to be 3.27 tonnes CO_2e/tonne crude oil.

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

2.2. Export Rebates

If there were an upstream GHG tax of $20 per tonne of CO_2 levied on produced crude oil, the export rebate for crude oil would be ($20/tonne of CO_2)(3.27 tonnes CO_2e/tonne crude oil) = $65.40 per tonne crude oil ($8.84/BBL).

2.3. Import Charges

A significant amount of crude oil is imported into the United States from many different countries and diverse oil fields. Commercial firms with data (such as S&P Global) can provide information about crude oil from various countries that can be used to estimate GGIs for crude oil imports. Relevant information is also available from a variety of sources (as described in our Framework report; see footnote 3), including from many nations that already require GHG reporting from facilities in energy-intensive, trade-exposed and other GHG-intensive sectors.

The average GHG emissions from fuels used to produce electricity in the relevant country should be used to determine the CO_2e emissions from electricity use associated with the production of the imported oil and gas products—unless and until more specific, verifiable information for the nation as a whole (or for individual firms) is provided to the Regulator.[11]

[10] Lattanzio, R. 2014. Canadian Oil Sands: Life-Cycle Assessments of Greenhouse Gas Emissions. CRS Report R42537. Congressional Research Service.
[11] Such electricity information can be found in the IEA's World Energy Balances 2020. **https://www.iea.org/data-and-statistics/data-products?filter=balances%2Fstatistics**

We recommend that information on the GGIs of GHG-intensive products imported from other nations be reported by firms that import covered products into the United States within two years after the program commences. Until such data are available, the Regulator could use the GGIs estimated here for such imports (as estimated based on US crude oil production), while requiring the importer to provide verifiable information about the GGIs of exports to the United States. It will be important for the exporters to the United States to determine or estimate all sources that would contribute to GGI in the United States in the course of producing crude oil. Besides the carbon content of produced oil and associated products, these would include contributions from GHG process emissions and sources associated with covered, GHG-intensive purchased products, especially electricity and commercial fuels. Such emissions can vary widely among producers. For example, GHG emissions resulting from the production of oil from oil sands are usually at least twice those from more conventional sources (see Figure 3 in the source in footnote 8), though they vary considerably depending on the specific resource and technology used to extract and process oil sands. That information would enable the Regulator to adjust import charges for those imports to be based on their GGIs.

If there were an upstream GHG tax of $20 per tonne of CO_2 and the import charge was based on the generic US GGI for crude oil of 3.27 tonnes CO_2e/tonne crude oil, the import charge would be $65.40 per tonne ($8.84 per BBL).

3. Natural Gas

If natural gas consisted solely of methane, then, based on its carbon content, the contribution to GGI from combustion alone would be 44 tonnes CO_2/16 tonnes methane (i.e., 2.75 tonnes CO_2/tonne methane). However, natural gas is not pure methane, so its carbon content will be higher. As well, operations to extract and process natural gas result in GHG process emissions and utilize GHG-intensive products, such as fuels and electricity, that need to be accounted for to evaluate the GGI of natural gas.

This analysis assumes that average natural gas is a mixture of predominantly methane but also heavier hydrocarbons. In this analysis, the non-hydrocarbon components of the natural gas are disregarded. According to Liquified Gas Carrier, liquified natural gas has an analysis reflecting methane at 89.63 percent, ethane at 6.32 percent, propane at 2.16 percent, butanes at 1.20 percent, and nitrogen at 0.69 percent.[12] The molecular weight of methane is 16, the molecular weight of such natural gas (which includes the gases in addition to methane) is 17.88.

EPA's Inventory of US Greenhouse Gas Emissions and Sinks 1990–2018 (see footnote 5) provides in Tables 3-67 and 3-72 the CH_4 (methane), CO2 and N2O emissions from exploration, production, and processing of natural gas in 2018. These, excluding N2O and distribution and other operations amount to 179.1 million tonnes of CO_2e. EIA reports that there were 83.8 billion cubic feet of dry gas produced per day in 2018.[13] Assuming the density of dry gas is 0.050 lb/cubic foot[14] or 0.0227 tonnes/thousand cubic feet, the amount of gas produced in 2018 was 694 billion tonnes. Thus, the contribution to GGI of natural gas from exploration, production, and processing is 0.258 tonnes CO_2e/tonne natural gas. This contribution amounts to an additional 9 percent relative to the carbon content of natural gas (see below).

Assuming a methane concentration in natural gas of 0.896, its contribution to the molecular weight of natural gas is (0.896)(16) or 14.34. Similarly, assuming ethane, propane, and butane concentrations are 0.0632, 0.0216, and 0.012, respectively, their contributions to the molecular weight of natural gas are 1.89, 0.95, and 0.70—for a total of 3.54. The hydrogen and carbon content of the methane and the higher hydrocarbon content, assuming their average molecular weight is 44 would be as follows:

[12] *See*: **http://www.liquefiedgascarrier.com/LNG.html**.
[13] EIA. 2019. "Today in Energy." November 15.
https://www.eia.gov/todayinenergy/detail.php?id=41955
[14] *See*: **https://www.engineeringtoolbox.com/gas-density-d_158.html for density of natural gas**

	Hydrogen	Carbon
14.34 moles methane	3.585	10.755
3.54 moles higher HCs assuming average mol. wt. of 44	0.643	2.89
	4.23	13.65

The mole of natural gas input has hydrogen weight of 4.23 and carbon weight of 13.65—for a total weight of 17.88. So, the carbon fraction by weight of natural gas is 0.763. Thus, the GGI for this natural gas—based on its hydrocarbon content and GHG process emissions from operations, but not accounting for CO_2 emitted by combustion during its production—would be as follows:

$$\begin{aligned} \text{GGI} &= CO_2e(\text{TOT})/\text{tonne natural gas}; \\ &= [0.763\ (44/12) + 0.258]\ \text{tonnes}\ CO_2e/\text{tonne natural gas} \\ &= 3.06\ \text{tonnes}\ CO_2e/\text{tonne natural gas.} \end{aligned}$$

3.2. Export Rebates

This information applies to natural gas exports by pipeline. A separate module addresses LNG exports. If there were an upstream GHG tax of $20 per tonne of CO_2, the export rebate per tonne of natural gas would be (3.06 tonnes CO_2e/tonne natural gas) ($20/tonne CO_2) = $61.20.

3.3. Import Charges

Since most of world's production of natural gas is done by the same or similar processes as assumed for the United States, the GGIs developed for the United States should initially be used to establish import charges for natural gas. Gas is imported to the United States by pipeline from Canada and very small amounts are also imported by pipeline from Mexico. Also, there are imports of LNG to the United States from various countries (these are covered in a separate module concerning exports and imports of LNG). If a natural gas exporter to the United States has a lower GGI for its gas than that developed for the United States, it may provide verifiable information of that situation to the Regulator. Then, based on verifiable information, the Regulator will be able to adjust the import charge for the country and product.

If there is an upstream GHG tax in the United States of $20 per tonne of CO_2, the initial import charge per tonne of natural gas would be ($20/tonne of CO_2) (3.06 tonnes CO_2e/tonne natural gas) = $61.20, until the company-specific data are provided. The same charge would apply to all other natural gas imports until such time as the exporter provided verifiable data that its exported natural gas has a different GGI.

Finally, because of its large global warming potential, we note that flaring, venting, and leaking of natural gas during production, processing, and transport (and conversion to LNG) are subject to intense ongoing scrutiny, debate, and controversy, in part because they appear to be very site-specific. Under the Framework, contributions to

GGI occur only from taxed sources of emissions. Thus, such venting, flaring, and leaking of natural gas during production itself and then its transformation to LNG (see companion module) would be covered if such emissions were determined and taxed.