RESOURCES *for the* FUTURE

The Greenhouse Gas Index for Products in 39 Industrial Sectors

Brian P. Flannery and Jan W. Mares

Working Paper 22-16
September 2022

About the Author/Authors

Brian P. Flannery is a visiting fellow at Resources for the Future. Dr. Flannery joined RFF in 2012 where he continues involvement in climate and energy issues that began when he joined Exxon's Corporate Research in 1980. He retired from Exxon Mobil Corporation in 2011 as Science, Strategy and Programs Manager. At Exxon, he conducted and supported climate research, and organized international meetings on climate-related science, technology, economics, and policy. As an observer for industry and continuing at RFF he followed and reported on IPCC assessments and negotiations under the UN Framework Convention. At Exxon Flannery played a leadership role creating the Joint Program on the Science and Policy of Global Change (MIT) and the Global Climate and Energy Project (Stanford).

Flannery has served on numerous editorial and advisory boards, among them: Stanford University School of Engineering, and Annual Reviews of Energy and Environment, and participated in assessments by the US DOE (climate modelling and scenarios) and EPA (climate impacts), and IPCC Working Group III. He served with business associations including the International Chamber of Commerce (Vice-Chair, Environment and Energy Commission), US Council for International Business (Chair, International Energy Working Group), Major Economies Business Forum (Chair, Task Force on Business Engagement).

Before Exxon, Flannery pursued a career in astrophysics with degrees from Princeton (1970) and UC Santa Cruz (PhD 1974) and as a post-doctoral associate at the Institute for Advanced Study and assistant and associate professor at Harvard. Flannery is coauthor of the reference book Numerical Recipes: The Art of Scientific Computing.

Jan W. Mares is a senior advisor at Resources for the Future where he has been involved with work on energy and environmental issues since 2009. From 2003 to 2009, he was Deputy Director of the Private Sector Office of the Department of Homeland Security. During the Reagan Administration, Mares was an Assistant Secretary of Commerce for Import Administration for about a year, a Senior Policy Analyst at the White House and for four years was three different Assistant Secretaries of Energy including for Fossil Energy. Before entering Federal service, Mares was with Union Carbide Corporation for about 18 years. About nine years were in the Law Department, where he worked on antitrust compliance and purchasing issues as well as spending seven years on issues involving Union Carbide's overseas activities and became the International Counsel. The other nine years involved business responsibilities in the chemicals area. They included leading an effort for three years to create a chemicals joint venture with a Middle East government company and being the operations/profit manager for several groups of industrial chemicals. From early 1980, until joining the Department of Energy in 1981, he was Vice President-General Manager of the Ethylene Oxide Derivatives Division.

Acknowledgements

The authors benefited greatly from discussions with our colleagues and coauthors on related papers: Jennifer A. Hillman and Matthew C. Porterfield and their students at Georgetown University Law Center; staff from a number of trade associations for energy intensive industries; and David Bailey and Catrina Rorke at the Climate Leadership Council (CLC). They also recognize the significant contribution of our editor Adrienne Young to this report and others in our series of work on border adjutsments. Flannery acknowledges financial support from the CLC for research on border adjustments.

About RFF

Resources for the Future (RFF) is an independent, nonprofit research institution in Washington, DC. Its mission is to improve environmental, energy, and natural resource decisions through impartial economic research and policy engagement. RFF is committed to being the most widely trusted source of research insights and policy solutions leading to a healthy environment and a thriving economy.

Working papers are research materials circulated by their authors for purposes of information and discussion. They have not necessarily undergone formal peer review. The views expressed here are those of the individual authors and may differ from those of other RFF experts, its officers, or its directors.

Sharing Our Work

Contents

The Sectoral Modules

Fossil Fuel Resources, Fuels, Feedstocks, and Electricity

M1	**Coal Mining (3 sectors)**
M2	**Crude Oil and Natural Gas (2 sectors)**
M3	**Liquified Natural Gas**
M4	**Petroleum Refineries**
M5	**Fossil Fuel Electric Power**

Sectors under the European Union's Carbon Border Adjustment Mechanism

M6	**Iron and Steel** — Updated February 2023
M7	**Alumina and Aluminum (4 sectors)**
M8	**Nitrogenous Fertilizer** — Updated February 2023
M9	**Cement**
M10	**Lime**

Other GHG-intensive sectors

M11	**Petrochemicals**
M12	**Plastic Material and Resin** — Updated February 2023
M13	**Basic Organic Chemicals** — Updated February 2023
M14	**Basic Inorganic Chemicals**
M15	**Glass (3 sectors)**
M16	**Pulp**
M17	**Paper Mills**
M18	**Paperboard**
M19	**Newsprint**
M20	**Converted Paper Products (7 sectors)**
M21	**Wet Corn Milling**
M22	**Industrial Gases**
M23	**Synthetic Rubber**
M24	**Copper Ore**
M25	**Copper Products**

1. Introduction

In recent work, we proposed the GHG index (GGI) as a central concept and administrative tool to determine border adjustments (BAs)—export rebates and import charges for covered products.[1] With colleagues Jennifer Hillman and Mathew Porterfield (both at Georgetown University Law Center at the time), we initially developed the GGI in the context of a potential upstream US GHG tax. Our Framework report describes how GGIs could be used to determine border tax adjustments (BTAs) compatible with World Trade Organization (WTO) obligations.[2] Among other criteria for WTO compatibility, the GGI incorporates relevant aspects of recognized international standards to determine the GHG emissions from an industrial facility and its supply chain, and then allocates them to products it manufactures (see Section 3 of the Framework). Essentially, a product's GGI, which is expressed as tonnes of CO_2 equivalent (CO_2e) per tonne of product, multiplied by the GHG tax rate (US$ per tonne of CO_2) determines its BTA (US$ per tonne of product). Note that the GGI itself does not depend on the policy used to set a GHG price. Rather, it is a technical metric, based on physical quantities associated with products (i.e., the carbon content of produced fossil resources and GHG process emissions required to create covered products used and produced by manufacturers). For that reason, the GGI could be used in the context of climate policies for BAs other than a GHG tax—or, more generally, as the basis for an international metric that associates GHG emissions with GHG-intensive products for various analyses and policies.

For BAs based on a range of policies (besides a tax) that are now under consideration (see footnote 1), the GGI could serve as a metric to assign GHG emissions to products as the basis to apply a price, if there were an objective way to determine the effective GHG price for covered products of these policies. Proposals include the Coons–Peters bill (the FAIR Transition and Competition Act of 2021) and other recent US legislative proposals based on a variety of price-based and regulatory policies,[3] as well as the European Union's (EU's) Carbon Border Adjustment Mechanism (CBAM) based on the EU Emissions Trading System (EU ETS), which applies to facilities, not products. Both provide for BAs only for imports, not exports. The Coons–Peters bill requires procedures both to determine an effective price for US GHG emissions and to assign GHG emissions to imported products. CBAM, which calls for emissions permits for imports, requires procedures to assign emissions to covered products (not facilities). Both proposals also require procedures to determine the effective

1 Flannery 2021. *Accounting for Emissions in Global Trade with a Greenhouse Gas Index*. Washington, DC: Resources for the Future. **https://www.resources.org/common-resources/accounting-for-emissions-in-global-trade-with-a-greenhouse-gas-index/**

2 Flannery, Brian P., Jennifer A. Hillman, Jan W. 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/**

3 See, for example, the Whitehouse bill (The Clean Competition Act 2022); **https://www.congress.gov/bill/117th-congress/senate-bill/4355?r=8&s=1**.

price of GHG policies in nations from which they import covered products. While designing procedures to determine effective GHG prices pose significant challenges (see discussion in the reference cited in footnote 1), here we focus on the potential application of the GGI to assign emissions as the basis to apply a price or charge to covered products.

Our related Policy Guidance report[4] discusses tasks for legislators and regulators[5] to authorize and implement the Framework. Of note, these tasks include procedures to promote continuous improvement as national and international climate policies and practices inevitably evolve. In particular, they include an appeals process allowing affected parties to challenge information from exporters and importers that they suspect to be incorrect, incomplete, or fraudulent. This appeals process recognizes and relies on existing capabilities of US regulators to conduct investigations in foreign nations regarding relevant data for covered, imported products.

In the 25 modules that follow, we provide procedures and information to estimate indicative values of the GGIs for representative, covered products. These modules cover 39 industrial sectors and over 100 individual products, as listed in the North American Industry Classification System (NAICS). As discussed in a related working paper,[6] these procedures rely on information from publicly available sources, such as national average values of products and the resources required to produce them. Our work on this project is ongoing. We are preparing additional modules that cover other sectors. We note that other nations classify covered sectors and products in different ways, and that sectors with similar names in different nations may not include identical products.

The modules demonstrate the feasibility of determining indicative estimates for GGI values. They also provide a basis to inform the development of official procedures for BTAs by the regulators in the United States, as well as to engage input from affected

4 Flannery, Brian P., Jennifer A. Hillman, Jan W. Mares, and Matthew C. Porterfield. 2020. *Policy Guidance for US GHG Tax Legislation and Regulation: Border Tax Adjustments for Products of Energy-Intensive, Trade-Exposed and Other Industries*. Washington, DC: Resources for the Future. **https://www.rff.org/publications/reports/policy-guidance-us-ghg-tax-legislation-and-regulation/**

5 In Section 3 of the policy guidance report (footnote 4), we proposed that the US Department of the Treasury should establish a new office as the lead agency to manage implementation of the Framework with assistance from the US Environmental Protection Agency and Department of Commerce. We referred to this set of agencies as the US "Regulator" that would be responsible, among other tasks, for administering BTAs under the Framework. In this introduction to the modules, we refer to US and other national officials responsible for administering BAs as "regulators" but use "Regulator" as defined above throughout the modules.

6 Flannery, Brian P., and Jan W. Mares. 2021. "Export Rebates and Import Charges for Border Tax Adjustments under an Upstream US GHG Tax: Estimates and Methods." Working paper 21-32. Washington, DC: Resources for the Future. **https://www.rff.org/publications/working-papers/export-rebates-and-import-charges-for-border-tax-adjustments-under-an-upstream-us-ghg-tax-estimates-and-methods/**

industries. We use a variety of publicly available sources of national and sectoral averages for key factors that contribute to GGIs (e.g., average GHG emissions for electricity generation, fuels for thermal energy, and GHG process emissions in key sectors). We refer to these estimates for the GGIs of products as "indicative" and "representative" because they are based on a variety of sources and, for the most part, use average factors rather than facility-specific information. Note that we do not aim to determine GGI values for all possible covered products; rather, we do so for a representative set to demonstrate the process. In many cases this involves only a single product. We used data from national agencies, international institutions, industry and academic sources, and, in a few cases, our own estimates. The GGI values are representative of national averages, rather than actual determinations of the GGI for products of specific facilities, which can differ significantly from national averages.

These estimates and procedures to determine the GGI provide a starting point for regulators and manufacturers to determine initial values for export rebates and import charges of GHG-intensive products based on their GGIs. The approaches could be especially useful as a model or template for the US regulators to determine initial import charges based on average values of GGIs for products (or groups of products) exported to the United States from nations that do not currently require detailed reporting of GHG emissions from industrial facilities. In practice, under the Framework, the regulators would develop official estimates for initial import charges based on more up-to-date information using uniform procedures within a sector to allocate emissions from manufacturers to the products they create. During an initial two-year start-up period, import charges would be determined by the US regulators based on national average values of the GGIs for imports. After the start-up period, GGI values for products imported into the United States would be based on facility- and firm-wide averages (as required for US manufacturers seeking export rebates, see immediately below). The start-up period would allow time for capacity building by foreign governments and firms that export to the United States to implement available international procedures to determine GGI values (see Section 3.1 of the Framework). As well, even in the initial years, if the foreign exporter had firm-wide data demonstrating lower values for the GGIs of their products, they would be entitled to appeal for a reduced import charge.

In a related working paper,[7] we describe procedures that would be used to determine GGI values for covered products manufactured in specific facilities, and the use of domestic firm-wide averages as the basis to claim rebates for exports from the United States. In the United States, the information required to determine such GGI values exists and much of it is publicly reported annually. This information could be used by the US regulators to develop authorized procedures for facilities to determine and report their GGI values as the basis for firms to claim export rebates based on their entire domestic production of each covered product.

7 Flannery, Brian P., and Jan W. Mares. 2021. "Determining the Greenhouse Gas Index for Covered Products of Specific Manufacturers." Working paper 21-31. Washington, DC: Resources for the Future. **https://www.rff.org/publications/working-papers/determining-greenhouse-gas-index-covered-products-specific-manufacturers/**

2. Overview of the Modules: Determining Border Adjustments for Products Based on their Greenhouse Gas Index

The modules provide indicative estimates of GGIs for illustrative commodity products in major industrial sectors. Although such sectors are often referred to as energy-intensive, trade-exposed (EITE) sectors, it remains unclear exactly how EITE sectors should be defined. Other nations include different sectors for coverage under their reporting and regulatory procedures depending, in part, on their circumstances and climate policies. Eligibility criteria for BTAs under the Framework apply to products rather than to entire sectors. To be covered for BTAs, the Framework proposes threshold values for the GGIs. For a covered product, the proposed threshold is 0.50 tonnes CO_2e/tonne of product; for electricity, the threshold is 0.25 tonnes CO_2e per MWh (where CO_2e denotes equivalent CO_2 emissions from all taxed sources of GHGs). We refer to covered products as GHG-intensive products. With these thresholds, it appears that major commodity products of traditional EITE sectors as typically discussed in US policy would be covered.[8] In addition to those cited in the interagency report (see footnote 8), they include production of coal, oil, natural gas, refined petroleum products, liquefied natural gas, and a few others, as well as electricity produced from burning fossil fuels. In total, these sectors encompass the vast majority of GHG emissions from US industrial sources.

Each module provides an overview based on the assumption as proposed in the Framework that the United States adopts an upstream GHG tax with BTAs for GHG-intensive products. The rate of the export rebate (US$ per tonne) is given by the GGI of the product (tonnes CO_2e per tonne of product) multiplied by a US GHG tax rate (US$ per tonne of CO_2). Similarly, the import BTA for a product is determined by its GGI multiplied by a US GHG tax rate. For BTAs determined here, we use $20 per tonne of CO_2 as the US GHG tax rate (a starting value in in some proposals for US GHG legislation).[9]

8 See Section 3.5 in the Framework, which discusses a 2009 interagency report led by EPA that detemined (and listed by their NACIS Code) 46 EITE sectors eligible for relief under the proposed Waxman-Markey cap-and-trade legilsation (HR 2454); **https://www.epa.gov/sites/production/files/2016-07/documents/interagencyreport_competitiveness-emissionleakage.pdf**.

9 US legislative proposals contain a variety of start-up values for the GHG tax rate and procedures for it to increase over time. For more information, see **https://www.rff.org/publications/data-tools/carbon-pricing-bill-tracker/**.

For sectors in the NAICS codes we report on, the modules provide information on the following:

- scale of US domestic production, exports, and imports;
- principal covered GHG-intensive products;
- major contributors to the GGIs of its products;
- procedures to allocate total taxed sources of GHG emissions to covered products;
- indicative values and potential ranges of GGIs for sample products;
- any special circumstances that pertain to the sector; and
- estimates of export rebates and import charges for products based on calculations of the GGIs and using the assumed value $20 per tonne of CO_2 for the US GHG tax rate.

2.1. Contributors to GGI

Under the Framework, the GGI would be determined for GHG-intensive products produced in a specific facility (or operation, e.g., to produce coal) based on three sources:

- the carbon content of produced fossil resources (coal, oil, and natural gas);
- GHG process emissions from operations of the manufacturer (if any, e.g., CO_2 from calcining limestone); and
- GHG emissions (determined by their GGIs) for raw materials and electricity purchased from suppliers.

Determinations of GGIs could be made for products of specific facilities in the United States where detailed information would be available at the start of the program.[10] Note that emissions from fuels used for transportation are not considered in any of the modules because of the enormous difficulty of determining and verifying such emissions, especially for the large number of covered products.[11]

Many EITE sectors (e.g., steel, aluminum, glass, pulp, and paper) make extensive use of recycled materials, often referred to as scrap. As discussed in Section 4.3 of the Framework, scrap acquired through the supply chain is assigned a GGI of zero. This recognizes the fact that scrap is not a product of an EITE manufacturer; rather, it is a product of the entity that collects it for reuse. As well, the gathering process may combine materials from many sources, making it impossible to determine the provenance of recycled materials (e.g., the facility that originally manufactured it or

10 See Section 4 in Flannery, Brian P., and Jan W. Mares. 2021. "Determining the Greenhouse Gas Index for Covered Products of Specific Manufacturers." Working paper 21-31. Washington, DC: Resources for the Future. **https://www.rff.org/publications/working-papers/determining-greenhouse-gas-index-covered-products-specific-manufacturers/**

11 See Section 4.4 in the Framework for additional discussion of transport.

the date of production). Manufacturers benefit from using scrap because it requires far less energy to be reprocessed into new products than is required to convert raw materials. This lowers costs, reduces GHG emissions, and results in smaller GGI values for products made using scrap than those for similar products made using only fresh raw materials. Use of scrap may also affect the performance of products.

For compatibility with WTO rules, as we describe in the Framework, a product's GGI is determined in a fashion analogous to value-added taxes. The GGI tracks cumulative GHG process emissions and the contribution of the carbon content of products derived from fossil resources—CO_2e(TOT)—from operations of the facility and those along the supply chain to produce GHG-intensive products used by the manufacturer. CO_2e(TOT) includes the following contributions:

- Carbon content: The carbon content in products of produced fossil resources (coal, oil, and natural gas) expressed as tonnes of CO_2 per tonne of product, under the assumption that 100 percent of the carbon in the products will ultimately be emitted as CO_2.
- GHG process emissions: GHG emissions (if any) that occur to produce fossil resources or manufacture GHG-intensive products.
- Purchased products: GHG-intensive products (e.g., electricity, commercial fuels, and feedstocks) purchased by the manufacturer from suppliers based on the product's GGI.

At this time, detailed data required to determine the GGIs of products from specific US or foreign facilities are not entirely publicly reported. So, these modules use publicly available information for GHG emissions and products in sectors and nations, largely based on national and sectoral averages for the key contributors to GGI values. Besides the carbon content of produced fossil resources and GHG process emissions from operations (both of which would be taxed under the Framework), significant contributions also come from products purchased from suppliers. Contributions from the supply chain come from GHG-intensive feedstocks and other raw materials, fossil fuels used for thermal energy, and electricity generated from fossil fuels. Where available, we use estimates from these modules for the GGI values of fuels, major feedstocks (e.g., crude oil, petrochemicals, and pulp), and other materials used to manufacture more refined or finished products.

There are two major steps to determine GGI values of products for a specific manufacturer (see footnote 7), and, in a similar fashion, the average GGI values for products of an entire sector (as described in these modules and in more detail in the related working paper on estimates and methods; see footnote 6). The first, as described above, is to determine CO_2e(TOT)—the input from contributing sources of GHG emissions along the production and supply chain (measured in tonnes of CO_2e) required to create products by the manufacturer or sector. The second is to allocate this total to the entire slate of covered products created by the specific manufacturer or sector.

2.2. Allocation of Emissions to Covered Products

These modules use the following two principal approaches to determine the GHG emissions allocated to a product:

- **Allocation by carbon content**—this applies to produced fossil resources (coal, oil, and natural gas) and products derived from them (e.g., petrochemicals and refined petroleum products). Allocation by carbon content is based on first determining the average CO_2e emissions per tonne of carbon (C) in all products, $<CO_2e/C>$, of the facility or sector:

  $<CO_2e/C> = CO_2e(TOT)/M(C)$, where M(C) is the total weight of carbon in all products.

  Then, for each product, the GGI is determined as follows:

  GGI = $<CO_2e/C>$ *cf*, where *cf* is the fraction of carbon by weight in that product.

  In situations where the facility produces a single product, and so *cf* = M(C)/M(P) where M(P) is the total mass in all covered products, the GGI = $CO_2e(TOT)/M(P)$.

- **Allocation by weight**—this applies to inorganic products (e.g., steel and cement). This approach allocates overall emissions—$CO_2e(TOT)$—to products based on their content by weight of what we refer to as the "core product" of the sector or manufacturer of a particular product. Creation of the core product (e.g., raw steel or unwrought aluminum) requires the vast majority of energy consumed and contributions from GHG-intensive products utilized by the manufacturer. Once produced, the core product often provides the underlying material or feedstock for other, more finished products that require comparatively little additional energy to fabricate. Allocation by weight of the core product is based on first determining the average CO_2e emissions per tonne of core product, (P), in all products produced by the facility or sector:

  $<CO_2e/P> = CO_2e(TOT)/M(P)$, where M(P) is the total weight of all core product.

  Then, for each product, the GGI is determined as follows:

  GGI = $<CO_2e/P>$ *cp*, where *cp* is the fraction of core product by weight in that product.

  In situations where the facility produces a single product (i.e., *cp* =1), GGI = $CO_2e(TOT)/M(P)$.

Discussions in each module identify the major sources that contribute to the GGIs in the specific sector, sources of information on their GHG emissions, and the methods we propose to allocate total emissions (based on the GGIs of the inputs and operations of facilities in the sector) to the product slate it produces. In many sectors, allocation requires a single approach (e.g., based on the weight of GHG-intensive materials or their carbon content). However, in

more complex situations (e.g., where petrochemicals are concerned), allocation may require a number of procedures to deal with multiple individual product streams with separate production pathways that each require distinct considerations.

The modules provide "ballpark" values of GGIs for GHG-intensive products. We primarily use results from various published sources and estimates based on average national emissions from electricity production and the carbon content of fuels. Such estimates may not include all factors that would ultimately be included in such determinations. In particular, for electricity (see Table 1 in this overview), we use the US average values for CO_2 (not CO_2e) emissions from electricity generation as reported by the US Energy Information Administration. As described in the module for electricity, average GGI values based on CO_2e would be larger by small amounts ranging from a few to several percent or more. Moreover, results for CO_2e emissions evaluated on a life-cycle basis (see Table 2 in this overview) highlight the very wide range of estimated GHG emissions from electricity production around the world—even for electricity generation based on the same fuel (e.g., natural gas or coal). Consequently—and lacking more precise estimates—the well-documented average values for CO_2 emissions in Table 1 (below) serve as appropriate indicators for our purposes.

In all cases, estimates for GGIs are representative, indicative, and approximate values. In practice, under the proposed Framework, ultimately, each facility or production operation would be responsible to determine the GGIs for its products according to their actual circumstances using guidelines authorized by the US regulators.

3. Summary and Conclusions

The introduction and overview provide both baseline information and background context for readers who have not necessarily delved into the Framework report that is the foundation for this ongoing work. We also highlight here our related reports that describe how, in the context of a US upstream GHG tax, we formulated the concept of the GGI to assign GHG emissions to products as the basis for WTO-compliant BTAs.

Our latest reports also address how the GGI could serve as a generic metric that could be adapted to assign emissions to products for use in other (non-tax) policies and applications—such as those new legislative proposals in the United States mentioned above and the EU's CBAM. The GGI concept is widely adaptable for use in other applications, e.g., for procurement of products with lower GHG emissions, or by firms for corporate reports, planning, and research and development.

The overview section here specifically describes the procedures and publicly available information used to estimate indicative, representative values for the GGI of products in 25 modules that cover 39 industrial sectors and over 100 individual products. These estimates provide a starting point for regulators and manufacturers to determine initial values for export rebates and import charges for GHG-intensive products based on their GGIs. They also provide a basis to inform the development of official procedures for BTAs by the regulators in the United States, as well as to engage input from affected industries.

Overall, the modules demonstrate several important characteristics of the GGI tool that show its ability to provide a common metric for manufacturers to assign GHG emissions to individual products. The GGI metric can be used across industries and by their customers and stakeholders around the world in a variety of applications including border adjustments, procurement, accounting for clean production in various sectors, and by corporations for internal assessments and external reporting. Procedures and information to determine GGIs are straightforward and embody the following characteristics:

- **Comprehensive**: They include all GHG-intensive sources that contribute to GHG emissions required to manufacture products and, in the case of products derived from fossil resources, to utilize them.
- **Explicit**: The contributions to the GGI include GHG process emissions from all manufacturers, the carbon content of produced fossil resources, and emissions from GHG-intensive products purchased in the supply chain.
- **Applicable**: They apply in the same way to covered products in all sectors.
- **Adaptable**: Because the contributing factors are comprehensive and explicit, they can be tailored to other GHG control policies by including only those factors actually covered by the policy or application and excluding others (e.g., purchased electricity or the carbon content of feedstocks) if they are not covered under alternate policies.
- **Implementable**: Manufacturers will be able to determine the GGIs of products

they create based on information that is known or knowable. They will know covered sources of emissions from their own operations, and they will be able to request information from their suppliers concerning the GGI values of products that they purchase—notably, those from GHG-intensive feedstocks, electricity, and fuels used for thermal energy. They will also know the information required to allocate emissions to their GHG-intensive products based on their carbon content and weight of core product.

4. Note on Common References, Default Values, Acronyms and Abbreviations used in the Modules

The modules are not stand-alone documents—this is a key point. The work detailed in the modules and the GGI values described therein need to be understood in the broader context described in our Framework and other related reports that led to ultimately drilling down to industry and sectoral specific products in the modules.

Below we note material and reference sources that are used across the entire set of modules.

- Assumed, default values for CO_2 emissions from electricity generation (tonnes CO_2 per MWh) and fossil fuels used for thermal energy (tonnes CO_2 per MBtu) as listed in Table 1, below. These are based on US averages for use of coal, oil, and natural gas as reported by the US Energy Information Administration. Table 2 illustrates the wide range of GHG emissions from electricity generation around the world using similar fuels and technologies.
- A list of Common Acronyms and Abbreviations (provided at the end of this Introduction).
- Unless otherwise noted, value of US domestic production, exports, and imports by industrial sector:

  Exports and imports: The US Census Bureau provides annual information listed by the sector's NAICS code. **https://usatrade.census.gov/data/Perspective60/View/dispview.aspx.**
  Production:Annual Survey of Manufactures: Summary Statistics for Industry Groups and Industries in the US: 2018–2020: **https://data.census.gov/cedsci/table?q=AM1831BASIC&tid=ASMAREA2017.AM1831BASIC01**

- Average national CO_2 emissions from electricity generation: International Energy Agency. World Energy Balances (last update 2022);

https://www.iea.org/data-and-statistics/data-products?filter=balances%2Fstatistics.

The modules advise using national average values for CO_2 emissions from electricity in nations that export to the United States, unless or until an exporting manufacturer can provide verifiable information on their actual electricity use.

Navigating the cited websites of the Census Bureau and IEA can be complicated. We suggest that new users seek assistance from an experienced user to get started. In the case of trade data, to access information on exports and imports, users must first establish a (free) account. Access to the IEA data on national CO_2 emissions from electricity may require a subscription.

We also recommend the following sources and references (cited in many of the modules) for additional insights and information on national GHG emissions:

- *The Inventory of US GHG Emissions and Sinks* (**https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks**) contains extensive data prepared by the US EPA for submission to the United Nations Framework Convention on Climate Change (UNFCCC). The inventory is updated annually the most recent release in 2022 covers the period from 1990 to 2020. Note that "sectors" in the inventory are defined using standards established by the Intergovernmental Panel on Climate Change that do not correspond to those defined under NAICS codes. Similar reports exist for many other nations, in particular for all developed countries (as listed in Annex 1 of the UNFCCC).
- *The Oil Information 202O Edition* prepared by the International Energy Agency contains valuable information regarding oil products (see page 66) and a useful set of general conversion factors for energy (see page 64):

  https://iea.blob.core.windows.net/assets/97bc371b-cf81-4694-a84d-46ac4f0e6b4a/Oil_documentation-2020.pdf

5. Organization of the Modules

We have intentionally organized the modules based on operational groupings, rather than arbitrarily listing them alphabetically or according to their numerical NAICS codes (see Table 3).

5.1. Fossil Fuel Resources, Fuels, Feedstocks, Electricity, and LNG

The first group of five modules consists of those sectors that extract fossil resources and/or convert them into fuels, feedstocks, and electricity. Their products are used in essentially all industrial sectors and the economy at large. The Framework (see Section 5) describes the extensive interactions that occur among these five sectors.

5.2. Sectors Potentially Covered under the EU Carbon Border Adjustment Mechanism (CBAM).

The second group includes additional sectors covered under the EU ETS that will, or may also, be covered under the CBAM. Note that NAICS code designations for sectors and products in these modules may not precisely align with those in the EU ETS and CBAM that are based on Europe's combined nomenclature (CN) codes. The EU ETS cap-and-trade program requires covered facilities to surrender allowances for their GHG emissions. Under the CBAM, imported products in covered sectors will require similar allowances to account for the GHG emissions required to produce them. Unlike the ETS that applies to facilities, CBAM must assign GHG emissions to products. We believe that our GGI concept (perhaps with some modifications) could provide a basis to do so.

5.3. Other Sectors

The third set of modules includes sectors that may not initially be covered by CBAM, and some that likely will not be part of CBAM. Many of them were included in the 2009 Interagency Report (see Footnote 8).

Table 1. Reference CO_2 Emissions from Electricity and Thermal Energy Derived from Fossil Fuels

Fuel	Electricity (tonnes CO_2 per MWh)	Thermal Energy (tonnes CO_2 per MBtu)
Coal	1.00	0.0935
Oil	0.95	0.0733
Natural Gas	0.42	0.0532

Note: Cited rates are based on data from the US Energy Information Administration (US average values as posted in 2020). Active links below may now point to more recent, updated data, but emissions rates will remain closely similar.

Electricity (2018): **www.eia.gov/tools/faqs/faq.php?id=74&t=11**

Thermal energy: **www.eia.gov/tools/faqs/faq.php?id=73&t=11**

Table 2. Ranges of CO_2e Emissions from Electricity Generation

Technology	Mean	Low	High
		tonnes CO_2e/MWh	
Lignite	1.054	0.790	1.372
Coal	0.888	0.756	1.310
Oil	0.733	0.547	0.935
Natural Gas	0.499	0.362	0.891
Solar PV	0.085	0.013	0.731
Biomass	0.045	0.010	0.101
Nuclear	0.029	0.002	0.237
Hydroelectric	0.026	0.002	0.237
Wind	0.026	0.008	0.124

Source: World Nuclear Association. 2011. *Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources*. **www.world-nuclear.org/uploadedFiles/org/WNA/Publications/Working_Group_Reports/comparison_of_lifecycle.pdf.**

Table 3. Sectors, Products for Which GGIs are Estimated, and NAICS Codes in the Modules

Products	Sectors	Module	Sectors & NAICS Codes
			Production of Fossil Resources, Fuels and Electricity
4	3	1	Coal Mining: NAICS Code 212111, 212112, 212113
2	2	2	Crude Petroleum and Natural Gas: NAICS Code 211120, 211130
1	1	3	Liquified Natural Gas: NAICS Code 488999
11	1	4	Petroleum Refineries: NAICS Code 324110
1	1	5	Fossil Fuel Electric Power Generation: NAICS Code 221112
			EU CBAM Sectors
2	1	6	Iron and Steel: NAICS Code 331110
3	4	7	Alumina, and Aluminum: NAICS Codes 331313, 331314, 331315, and 331318
5	1	8	Nitrogenous Fertilizer: NAICS Code 325311
2	1	9	Cement: NAICS Code 327310
2	1	10	Lime: NAICS Code 327410
			Other Sectors
15	1	11	Petrochemicals: NAICS Code 325110
10	1	12	Plastic Material and Resin: NAICS Code 325211
8	1	13	Basic Organic Chemicals: NAICS Code 325199
8	1	14	Basic Inorganic: NAICS Code 325180
3	3	15	Glass : NAICS Codes 327211, 327212, and 327213
1	1	16	Pulp: NAICS Code 322120
1	1	17	Paper Mills (excl. newsprint): NAICS Code 322121
1	1	18	Paperboard: NAICS Code 322130
1	1	19	Newsprint: NAICS Code 322122
1	7	20	Converted Paper Products: NAICS Codes 322111, 322212, 322219, 322220, 322230, 322291, 322299
4	1	21	Wet Corn Milling: NAICS Code 311221
6	1	22	Industrial Gases: NAICS Code 325120
7	1	23	Synthetic Rubber: NAICS Code 325212
2	1	24	Copper Ore: NAICS Code 212230
16	1	25	Copper Products: NAICS Code 331410

5.4. Acronyms and Abbreviations

- BA(s)—border adjustment(s)
- BBL(s)—barrel(s) (e.g., BBL of crude oil)
- BTA(s)—border tax adjustment(s)
- Btu—British thermal unit (equivalent to 1,055 joules)
- CO_2—carbon dioxide
- CO_2e—carbon dioxide equivalent (e.g., of radiative forcing from GHGs)
- EIA—US Energy Information Administration
- EITE—energy-intensive, trade-exposed (e.g., EITE sectors, industries, etc.)
- EPA—US Environmental Protection Agency
- GGI(s)—greenhouse gas index (indexes)
- GHG(s)—greenhouse gas(es)
- GJ—Gigajoule
- HTS—Harmonized Tariff Schedule
- IEA—International Energy Agency
- kWh—kilowatt-hour
- kscf—1,000 standard cubic feet
- lbs—plural of pound (lb)
- LDPE—low-density polyethylene
- LNG—liquefied natural gas
- MBtu—million BTU (equivalent to 1,055 MJ)
- MJ—megajoule (million joules)
- MWh—megawatt-hour
- NAICS—North American Industry Classification System
- PFCs—perfluorochemicals
- ST—short ton (2,000 lbs, equivalent to 0.90718 metric tonnes)
- scf—standard cubic foot
- TJ—Terajoule (10^{12} joule)
- tonne—metric tonne
- VATs—value-added taxes
- WTO—World Trade Organization