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# Proof of Concept for a U.S. Air Emissions Physical Flows Account

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**Abstract** Measuring the physical flows of resources and waste between the economy and environment is a central component of environmental-economic accounting as outlined in the *System of Environmental-Economic Accounting (SEEA)*, the United Nations standard for environmental accounting.

This paper presents a *SEEA*-consistent proof-of-concept air emissions physical flows account for the United States. Primary data on emissions come from the U.S. EPA's Greenhouse Gas Inventory (GHGI). The proof-of-concept account covers 2012–2017 and presents tabulated emissions by industry along with examples of additional analytic indicators such as trends in industry emissions and trends in emissions per dollar value added.

Primary challenges in constructing this account are (1) adjusting the GHGI data from territory- to residency-based, and (2) attributing emissions to industries and institutional sectors. In this proof-of-concept account, emissions are adjusted to a residency basis using data on the activities of U.S. resident agents abroad and are attributed to industries in proportion to related measures of activity, like fuel purchases or output.

**Keywords** Air emissions, National accounting, Environmental accounting, Emissions inventories, *SEEA*

**JEL codes** E01, E20, I31, L92, L93, Q53, Q54, Q5

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# 1. Introduction

Around the world, countries maintain accounts of economic activity. Using these accounts, they compile and publish statistics such as gross domestic product (GDP) for use in public and private decision making. But the economy does not exist in a vacuum; it draws resources from—and disposes of waste to—the environment. Measurement of the impact of economic activity on the environment contributes to good long-term decision making by government and other stakeholders but is absent from traditional economic accounts.

Environmental-economic accounts (hereafter, environmental accounts) help fill this data gap. These accounts—compiled in parallel with traditional economic accounts—measure flows between the environment and the economy, the health of the environment, and environmentally related transactions within the economy. Recognizing the value of these measurements for decision making, the U.S. Office of Science and Technology Policy (OSTP), Office of Management and Budget (OMB), and Department of Commerce (DOC) recently published the *National Strategy to Develop Statistics for Environmental-Economic Decisions* (*SEED*), the first plan of its kind in the United States (OSTP, OMB, DOC, 2022).

Phase 1 of *SEED* includes an air emissions account; it is recommended that the physical flows account be developed first and that the U.S. Environmental Protection Agency (EPA) and DOC should then explore methods for attaching monetary values to these flows. This paper presents a proof-of-concept for the air emissions physical flows account, consistent with international standards. Notable trends based on this account include:

- a downward trend in utilities emissions
- an upward trend in agricultural emissions
- a strong downward trend in household and transportation industry fluorinated greenhouse gas (F-GHG) emissions balanced out by countervailing trends in other industries, especially manufacturing.

Following this introduction, section 2 discusses the *System of Environmental-Economic Accounting* (*SEEA*), the international environmental accounting standard. Section 3 outlines related work on measuring air emissions (and attributing them to industries) and developing *SEEA*-consistent environmental accounts by EPA, the U.S. Bureau of Economic Analysis (BEA), and the U.S. Geological Survey (USGS); in particular, the relationship of this account to EPA's existing *Greenhouse Gas Inventory* (*GHGI*) is discussed. The methodology, data sources, and software tools used in compiling this account are described in sections 4, 5, and 6, respectively. Section 7 presents summary results and findings. Section 8 concludes with a discussion of challenges encountered and further work to be done in refining this account. Supply and use tables for this proof-of-concept account are given in appendices 1 and 2.

# 2. System of Environmental-Economic Accounting

International standards for both economic accounting (the *System of National Accounts*, or *SNA*) and environmental accounting (the *System of Environmental-Economic Accounting*, or *SEEA*) are published by the United Nations (United Nations Statistics Division, 2008; United Nations Statistics Division, 2012). These standards are designed for consistency in accounting methodology between countries and across years, and for comparability with each other.

## A. Categories of SEEA Accounts

*SEEA* outlines three categories of accounts: environmental flows (physical and monetary), economic activities related to the environment, and stocks of environmental assets. Environmental flows accounts track the movement of natural resources, pollution, and waste between the economy and the environment; these flows may be expressed in either physical units or in monetary units. Environmental activity accounts measure the value of goods and services produced within the economy for the purposes of environmental protection or resource management; these accounts are unique among *SEEA* accounts in consisting of economic transactions already covered by the *SNA*. Environmental asset accounts focus on measuring the stocks of individual, specific environmental assets, such as water or timber; they are related to ecosystem accounts[2] but do not account for the relationships between individual environmental assets and other aspects of their ecosystems (including other environmental assets).

## B. Important Definitions and Concepts

Consistency and comparability of environmental and traditional economic accounts allows the two sets of accounts to be used in tandem to calculate reliable, relevant statistics describing the relationship between the economy and the environment. To achieve this comparability and consistency, the accounting principles and methods used in *SEEA* correspond to those used in *SNA*.

The *residency principle* and the *production boundary* are two of these principles; they help define the set of activities that are to be measured and included in the national accounts. Under *SNA* and *SEEA*, national accounts exclusively measure productive economic activities (or the environmental impacts of productive activities) engaged in by agents resident in the country of interest.[3]

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[2] Ecosystem accounts are covered by *SEEA Ecosystem Accounting*, an extension to *SEEA*.

[3] The residency principle defines the economy as a set of discrete units: economic agents resident in the country of interest. Defining and measuring the economy and its environmental impacts in this way lends itself to sector/industry level analysis since each of the discreet units whose economic transactions and environmental impacts are being measured can be assigned to a specific sector or industry (Høst-Madsen, 1967).

The production boundary defines productive economic activities: those that create, via a process under the control or management of the agent, a good or service that is (or could be) sold in a market. *SEEA* defines flows from the economy to the environment as flows that cross the production boundary, from a productive activity to the environment (examples in box 1).

The residency principle generally defines economic agents (business establishments, households, governments, and nonprofit organizations) as being resident in the country they are physically located in.[4] Exceptions include short-term business operations in another country; individuals staying temporarily in another country for work or leisure; and production units such as ships, airplanes, or fishing vessels that may operate outside of the national territory (example in box 1). In this paper, the term "U.S. resident" is used generically to refer to a U.S. resident economic agent (of any of the types listed above).

### Box 1. Environmental Account Principles: Examples in Context

*Residency Principle*

Emissions from a flight from New York City to London operated by a U.S. airline are included in the U.S. air emissions account. If the same flight were operated by a U.K. airline, those emissions would instead be included in the U.K. account.

*Production Boundary*

Note that the atmosphere is outside the production boundary. Consider emissions from

- an unintentional forest fire: excluded from the air emissions account because the fire is also outside the production boundary.
- cattle in a managed herd: included in the air emissions account.
- decomposition of solid waste: included if released to the atmosphere but excluded if captured and used in a productive process (such as power generation) because they remain inside the production boundary.

*Own-account Production*

Emissions from a local grocery store's delivery truck are attributed to the retail trade industry, not the transportation industry.

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[4] Residency may be independent from ownership; for example, a manufacturing plant located in the U.S. but owned by a foreign car company would be considered a U.S. resident business establishment (more specifically, a U.S. affiliate of a foreign multinational enterprise). Consequently, this plant's value added would be included in GDP and its emissions would be included in the air emissions account.

An apparent divergence between *SNA* and *SEEA* is in the treatment of goods or services produced by agents for their own use (*own-account* production). In *SNA*, these activities are generally not recorded directly.[5] In *SEEA*, the environmental impacts of these activities are recorded directly and attributed to the producing agent. This is not actually inconsistent; rather, the *SEEA* treatment follows directly from the *SNA* treatment, in that the economic value and environmental impacts of each own-account production activity are attributed to the same agent.

*SEEA* also provides specific guidance on attributing emissions from decomposing waste (such as in landfills). Because these emissions are not the result of current economic activity, they are attributed to a special "accumulations" category rather than to the waste management industry.

Finally, the relationship between industries and commodities is important in both economic and environmental accounting. Industries are defined according to SNA as a "group of establishments engaged in the same, or similar, kinds of [production] activity" (United Nations Statistics Division, 2008), while commodities are types of goods. Importantly, an industry may produce multiple commodities, and a commodity may be produced by multiple industries. For this reason, care must be taken not to use commodity-based data as if they were industry-based, or vice versa.

# 3. Related Work

This account connects to three existing strands of work within the U.S. government:

- Emissions inventories (EPA)
- Environmentally extended input-output modelling (EPA)
- SEEA-consistent environmental and natural capital accounting (BEA, USGS, OSTP, and others).

## A. Emissions Inventories

EPA's Greenhouse Gas Inventory (GHGI) measures U.S emissions of greenhouse gases in accordance with the standards established by the Intergovernmental Panel on Climate Change (IPCC) to satisfy U.S. obligations under the UN Framework Convention on Climate Change (UNFCCC) treaties. The IPCC standards differ from *SEEA* standards in several ways, due at least in part to the different purposes of the two standards (Intergovernmental Panel on Climate Change, 2006).

[5] Except in certain situations—such as own-account capital formation, flows related to ancillary activities by businesses, or household production of goods—these activities are reflected in the value of output (for businesses) or ignored (for households).

Most importantly, the IPCC standards require that the GHGI measure greenhouse gas emissions that occur in U.S. territory (including U.S. waters), while *SEEA* requires measuring emissions by U.S. resident agents wherever those emissions occur. In general, the most noticeable divergences between emissions measured on territory vs. residency basis are found in the various transportation industries and in the fishing industry, since transportation and fishing vehicles are frequently operated by U.S. resident businesses in international or foreign territory.

IPCC and *SEEA* standards also differ in their treatment of carbon sequestration (or removals) and of marine and aviation emissions. Carbon sequestration[6] is to be accounted for under the IPCC but not under *SEEA*, due to concerns that accounting methodologies for carbon sequestration are not yet sufficiently well developed. Emissions from fuel used by ships or aircraft traveling internationally are not included in any country's inventory under IPCC standards,[7] but SEEA requires that these emissions be included in the air emissions account of the country whose resident operates the ship or airplane. Adjusting for these differences between the IPCC and SEEA standards is a necessary step in compiling the air emissions account.

The GHGI provides emissions estimates in physical mass units (kilotons) as well as in units called "carbon dioxide equivalent units" ($CO_2e$). These units are useful for aggregating emissions across different greenhouse gases, since different gases have very different warming effects per kiloton of gas. This is necessary to make meaningful comparisons across industries that may have very different emissions signatures; for example, emissions from agriculture are primarily methane and nitrous oxide, while emissions from transportation are primarily carbon dioxide.

However, average atmospheric lifetimes also differ greatly among the different greenhouse gases, most of which are removed from the atmosphere over time through natural processes, such as chemical reactions with other gases; for example, methane breaks down in about 12 years, while nitrous oxide breaks down in about 121 years. As a result, the multiplier used to translate physical mass units of a gas into carbon dioxide equivalent units depends directly on the time horizon used in the analysis. Over a 20-year time horizon, methane's global warming potential is 84 times that of carbon dioxide; over a 100-year time horizon, methane's global warming potential is 28 times that of carbon dioxide (IPCC, 2014).

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[6] The removal of carbon from the atmosphere. This may occur through either natural means, as by plants transforming atmospheric carbon dioxide into biomass through photosynthesis, or artificial means, such as by storing carbon dioxide underground. Sequestration recorded in the GHGI is restricted to sequestration in plants and soils (using data on land use and forestry).

[7] A portion of these emissions are included by EPA as a memo item in the GHGI report, but they are not formally included in the inventory.

The GHGI uses global warming potential multipliers based on a 100-year time horizon.[8] This proof-of-concept account provides estimates in both carbon dioxide equivalent units (appendix 1) and physical mass units (appendix 2).[9]

## B. EPA U.S. Environmentally Extended Input-Output Model

The U.S. Environmentally Extended Input-Output (USEEIO) models are a family of environmental-economic models of U.S. goods and services production (Ingersen, Li, Young, Vendries, & Birney, 2022). More than 400 commodities' environmental life cycle impacts can be calculated using USEEIO.[10] The primary divergence between the USEEIO models and the proof-of-concept *SEEA* air emissions account is that USEEIO is designed to capture both direct and indirect environmental impacts of each industry, while the proof-of-concept *SEEA* account is focused on capturing *direct* emissions by each industry. Many of the environmental data tables used in the USEEIO model, including those that identify direct environmental impacts of each industry, are generated using a tool also developed by EPA called FLOWSA. Section C describes how this tool is used in creating the proof-of-concept *SEEA* air emissions account.

## C. Proof-of-Concept *SEEA*-Consistent Water and Land Accounts

Researchers from BEA and USGS have compiled initial proof-of-concept *SEEA*-consistent accounts for physical flows of water, water quality, and emissions of pollutants to water (Bagstad, et al., 2020) as well as for land cover, land use, and land value (Wentland, et al., 2020).[11] The water physical flows and emissions accounts, like the air emissions account described in this paper, fall in the SEEA category of environmental-economic flows. The water quality account and the three land accounts fall in the category of environmental asset accounts.[12]

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[8] The GHGI global warming potential multipliers are based on the 2007 version of the IPCC report cited above; the multiplier for methane used in the GHGI is 25, not 28.

[9] Since there is no meaningful way to aggregate physical mass units across different greenhouse gases, the many types of fluorinated greenhouse gases are left out of the physical mass unit tables, as are totals by industry.

[10] These mainly correspond to the commodities found in the BEA 2012 Detail IO tables, with some additional disaggregation.

[11] Temporal coverage of these accounts varies, reflecting availability of data. The water physical flows account covers 2000, 2005, 2010, and 2015; the water quality account covers 2002 and 2012; and the water emissions account covers only 2015. The land cover account covers 2001, 2006, 2011, and 2016; the land use account covers 2000; and the land value account covers three groups of years (each of which is aggregated together): 2002–2006, 2007–2011, and 2012–2016.

[12] Though as noted in Wentland, et al. 2020, there is conceptual overlap between land as an economic asset and land as an environmental asset.

The foundation of the water physical flows account is a set of physical supply and use tables for water, at the state and industry level. These tables show physical quantities of water drawn from the environment into the economy (uses) or released from the economy into the environment (supply), broken down by industry. Using this account, the authors derive several useful statistics, including water use by state, change in water use by state, proportion of water use by industry by state, and water productivity by industry by state. The water quality account treats water quality as an asset and uses data from a network of monitoring stations across the 48 contiguous states to estimate levels ("stocks") of six different water quality indicators: chloride, nitrate, total nitrogen, total phosphorus, total suspended solids, and specific conductance. They also show changes in the levels of these indicators between 2002 and 2012. The water emissions account presents data on emissions of nitrogen, phosphorus, organic enrichment, solids, and metals by the top 15 emitting U.S. industries. This account is compiled from a single regulatory database (EPA's PCS-ICIS database) covering only point source emitters, due to the lack of a national emissions inventory for water. The authors discuss additional data collection efforts that would be needed to maintain more complete water emissions accounts.

BEA and USGS researchers have also collaborated to compile proof-of-concept accounts for land cover, land use, and land value. Land cover accounts classify land according to its physical characteristics: land cover categories include open water/ice/snow, developed (with subcategories for development intensity), barren, forest, and cultivated cropland. Stocks of land in each category are estimated along with changes in stocks between reference years. Unlike land cover categories, land use categories can be tied to specific industries, using appropriate crosswalks. The land use account gives stocks of land in use by different industries, and with better data could show the change in these stocks over time. The land value account is compiled using a hedonic approach to estimate the value of land separately from the structures on it. The data to support this hedonic approach are detailed microdata on land transactions, land characteristics, and structure characteristics from Zillow. From these three land accounts, the authors derive several statistics relevant for decision making, including the change in urban, forest, and agricultural land cover over time and the relationship between land use and price and how that relationship differs by region and across time.

Both the water and land accounts highlight the need for high-quality source data, and the extent to which it dictates what *SEEA*-consistent accounts can be compiled, how thorough they can be, and how frequently they can be updated.

# 4. Methodology

The process for compiling the proof-of-concept air emissions account for the United States mirrors the process suggested by Eurostat for European countries constructing similar accounts (Eurostat, 2015):

1. Begin with primary source data on emissions from the national emissions inventory.
2. Align emissions with the residency basis and production boundaries described in *SEEA*. This is also typically done using secondary data sources, as described in section B.
3. Attribute emissions to industries (for business) and other institutional sectors including households. Typically, this is done using secondary data, such as data on fuel purchases or output, as described in section C.
4. Assemble the final estimates in tabular form.

**Box 2. Residency Adjustment: Examples in Context**

*Direct Estimation of Total Emissions*

Commercial air transportation emissions are estimated by multiplying fuel consumption data from the Bureau of Transportation Statistics' (BTS) *Fuel Cost and Consumption for U.S. Carriers* series by EPA jet fuel emissions factors. Since the BTS data already conform to the residency principle, these estimates replace the GHGI commercial air transportation emissions estimates.

*Direct Estimation of Adjustment*

Complete data on marine fuel consumption by U.S. residents are not available, but BEA collects data on fuel expenditures by U.S. marine carriers abroad and by foreign carriers in the United States. These data are combined with world average marine fuel price data to estimate the quantity of fuel consumed by each group. Quantity estimates are multiplied by EPA marine fuel emissions factors to estimate emissions by each group, which are respectively added and subtracted from the GHGI marine transportation shipping estimates

*Adjustment Proportional to Output*

Data on fuel consumption by U.S. trucks in Canada and Mexico or Canadian/Mexican trucks in the United States are not readily available, so the residency adjustment for truck transportation is made by multiplying estimated truck transportation emissions from the GHGI by the ratio of truck transportation output to truck transportation output minus net exports of truck transportation services (derivation in footnote 14).

## A. Primary Data Sources

The primary data source for this proof-of-concept air emissions account is the Greenhouse Gas Inventory (GHGI), discussed above. The GHGI represents a time series of estimated greenhouse gas emissions for the U.S. (U.S. Environmental Protection Agency, 2019) that is internally consistent (different estimates for different years use the same methodology and are therefore comparable with each other in a meaningful way) due to EPA's adherence to IPCC standards. Creating a *SEEA*-consistent multi-year air emissions account that is also internally consistent requires adjusting the GHGI data to a residency basis (discussed in section B) and attributing flows reported in the GHGI to industries (discussed in section C).

## B. Residency Adjustments

Adjusting GHGI emissions data from the territory basis required by IPCC to the residency basis required by *SEEA* can be done in one of three ways, depending on data availability (see box 2 for examples):

- direct estimation of total emissions
- direct estimation of the adjustment
- proportional adjustment based on output.

In some cases, emissions by U.S. residents can be estimated directly using data on fuel consumption by U.S. residents for a particular activity. Quantity of fuel consumed is multiplied by an *emissions factor* to arrive at an estimate of total emissions for that activity by U.S. residents agents (business establishments or households). This estimate then replaces reported emissions for that activity from the GHGI.

If fuel consumption data conforming to the residency basis are not available, it may be possible to directly estimate the emissions that need to be added and/or subtracted from GHGI emissions estimates to arrive at *SEEA* consistent emissions estimates. The emissions to be added are those by U.S. residents abroad, while those to be subtracted are those from foreign residents in the U.S.

Finally, if no estimate of fuel use or expenditure is available, an alternative approach is to use a measure of output. Estimated emissions from the GHGI can be multiplied by a ratio derived from industry output, imports, and exports to arrive at the adjusted emissions estimate.[13]

### C. Attribution to Industries

Per IPCC guidelines, EPA's GHGI report to the UN classifies emissions sources using a system based on the International Standard Industrial Classification (IPCC table 8.2), which does not map readily to the North American Industrial Classification System (NAICS) used by BEA in compiling the national economic accounts. For consistency, it is necessary that the air emissions account follow the same industrial classification as the economic accounts. For this reason, rather than using the GHGI common reporting format tables submitted to the United Nations as our primary data source, this account uses the GHGI Inventory Report (U.S. Environmental Protection Agency, 2019), which provides greater detail than the tables submitted to the United Nations. This additional detail is useful for attributing emissions to NAICS-based industries.

In the inventory report, emissions are broken down by type of emitting activity. Some emitting activities, such as manure spread over fields for fertilizer, are specific to certain industries. Other activities, such as coal combustion for stationary applications or operating trucks, are not specific to any one industry, so emissions from these activities must be attributed to specific industries using other data sources. Attributing emissions recorded in the GHGI across industries is a two-step process. First, GHGI activities are mapped to industries, which are defined using NAICS codes.[14] Many activities map directly to a single industry.

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[13] This method is used in this proof-of-concept account to estimate the residency adjustment for the truck transportation industry. Transportation services provided in U.S. territory by foreign-operated vehicles are imports of transportation services, while U.S. vehicles operating in foreign territory are exporting transportation services. The (territory based) GHGI reports emissions for vehicles operating in U.S. territory: domestic production consumed domestically plus imports of truck transportation services. To be consistent with *SEEA*'s residency basis, this account should report emissions by U.S. vehicles, whether those vehicles are operating domestically or exporting truck transportation services. If $D$ is domestic output consumed domestically, $x$ is exports, and $m$ is imports, the adjustment ratio $R$ for transportation services is derived by:

$$(D+m)*R = D+x$$

$$R = \frac{D+x}{D+m}$$

$$R = \frac{output}{D+x-x+m}$$

$$R = \frac{output}{output-(x-m)}$$

[14] Underlying estimates for this account use NAICS three- and four-digit industries. Results are aggregated to the NAICS two-digit level for publication.

For activities that map to multiple industries, emissions are attributed to those industries in proportion to some measure of polluting activity, such as fuel consumption or purchases of fuel products. Measures used in attributing emissions should be related as closely as possible to the polluting activity. For instance, when the activity reported in the GHGI is a form of fuel combustion, a nearly ideal measure is the quantity of fuel consumed, since this is very closely tied to the quantity of emissions released. Using less directly related measures of polluting activity for attribution makes stronger implicit assumptions. When the implicit attribution assumptions are violated, the estimated attribution is biased (see box 3 for a stylized example and box 4 for examples in context). Much of the work involved in compiling the air emissions account consists of identifying and selecting the measures of polluting activity to use in attributing emissions. Section 5.B contains more detail on data sources and measures of polluting activity used in this account.

**Box 3. Proportional Attribution: Stylized Description (see figure 1 for illustration)**

*Setup*

Consider two industries, *A* and *B*, a fuel product F, and secondary data sources SD1 and SD2. Suppose the following:

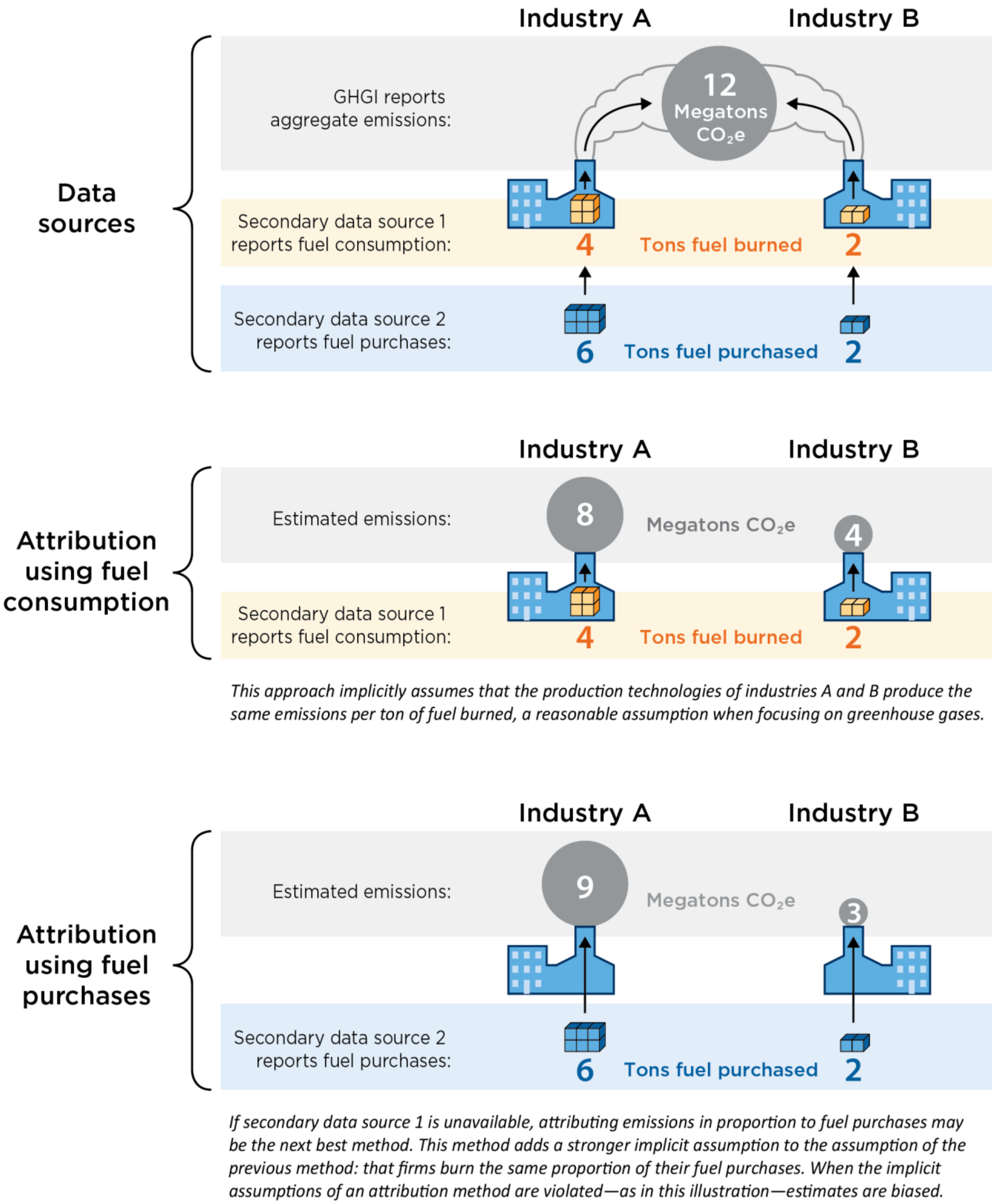
- Both industries produce emissions solely by burning *F*
- The GHGI reports aggregate emissions for *A* and *B* of 12 megatons $CO_2$
- SD1 reports that industry *A* burned 4 tons of *F*, while industry *B* burned 2 tons
- SD2 reports that industry *A* purchased 6 tons of *F*, while industry *B* purchased 2 tons (industry *A* increased its net inventory of *F*)

Attributing emissions in proportion to fuel consumption (using secondary data source *SD1*) yields estimated emissions of 8 megatons $CO_2$ for industry A and 4 megatons $CO_2$ for industry *B*. This approach implicitly assumes that the production technologies of industries *A* and *B* produce the same emissions per ton of fuel burned, a reasonable assumption when focusing on greenhouse gases.

*Attribution Using Fuel Purchases*

If data source *SD1* is unavailable, attributing emissions in proportion to fuel purchases may be the next best method, yielding estimated emissions of 9 megatons $CO_2$ for industry *A* and 3 megatons $CO_2$ for industry *B*. This method adds a stronger implicit assumption to the assumption of the previous method: that firms burn the same proportion of their fuel purchases. When the implicit assumptions of an attribution method are violated—as in this illustration—estimates are biased.

**Figure 1. Proportional Attribution: Stylized Illustration**



**Box 4. Proportional Attribution: Examples in Context**

*Fuel Consumption*

Emissions from coal combustion in manufacturing are attributed proportional to each industry's consumption of coal for energy, as given in the Energy Information Administration (EIA) Manufacturing Energy Consumption Survey (U.S. Energy Information Administration, 2018). Emissions from other industrial or commercial coal combustion are attributed proportional to each industry's coal purchases, as given in the BEA Use table.

*Transportation Satellite Accounts*

Emissions from trucking activities are attributed using the BTS Transportation Satellite Accounts, which provide estimates of the value of transportation services produced on own account by each industry, as well as by for-hire transportation industries (U.S. Bureau of Transportation Statistics, 2022). Trucking emissions are attributed to each industry in proportion to the value of truck transportation services produced by that industry.

# 5. Data

## A. Greenhouse Gas Inventory

The primary source of greenhouse gas emissions data for this proof-of-concept account is the national Greenhouse Gas Inventory (U.S. Environmental Protection Agency, 2019). EPA produces the GHGI every year to satisfy the requirements of the United Nations Framework Convention on Climate Change (UNFCCC), which sets international standards for the construction of greenhouse gas inventories. As a result of adherence to these standards, and because EPA re-estimates all earlier years when methodological improvements are made, the GHGI represents an internally consistent time series of estimated greenhouse gas emissions for the United States. This allows compilation of a multi-year air emissions account that is also internally self-consistent. The GHGI has a 2-year publication lag; as of this writing, the most recent data year published is 2020.

GHGI emissions estimates are organized by polluting activity, such as generation of electricity by burning coal, agricultural soil management, or aluminum production. In general, emissions for each activity are estimated by using activity data (such as fuel consumption or purchases, vehicle-miles traveled, or raw material processed) together with activity-specific emissions factors, which are multipliers expressing how much of each pollutant is generated by one unit of the given activity. Activity data are largely drawn from official government statistics, but academic studies, trade association surveys and statistical reports, and expert judgment are also used when necessary. Emissions estimates are also supplemented with data from EPA's Greenhouse Gas Reporting Program, through which around 8000 large-scale greenhouse gas emitting establishments are required to report their emissions to EPA annually (U.S. Environmental Protection Agency, 2019).

## B. Secondary Data Sources

Secondary data sources used in compiling this proof-of-concept account come from a variety of U.S. government and private sources. With one exception, the U.S. government data used is publicly available.

### i. Bureau of Economic Analysis

BEA's use table is a broadly useful secondary data source, with data on purchases of commodities by industries (U.S. Bureau of Economic Analysis, 2017). Commodities such as coal and petroleum products are used as proxies for industries' use of related fuels. Since the use table contains data for the whole economy, it serves as a fallback data source when more detailed sources of data do not have adequate coverage (for example, the EIA MECS survey is more detailed, but only covers manufacturing industries).

Unpublished BEA tabulations of fuel expenditures by U.S. and foreign shippers are used in estimating the residency adjustment for marine shipping.

### ii. Bureau of Transportation Statistics

The U.S. Bureau of Transportation Statistics (BTS) collects and reports data on the quantity of fuel consumed by major commercial air carriers, on all flights worldwide (U.S. Bureau of Transportation Statistics, 2022). Since this conforms closely to the *SEEA* residency principle, these data are used to directly estimate emissions from U.S. air transportation. This is done by multiplying the quantity of fuel consumed by an emissions factor obtained from EPA (U.S. Environmental Protection Agency, 2022) for each of the relevant greenhouse gas emissions (carbon dioxide, methane, and nitrous oxide).

To attribute emissions from trucking, an activity which is carried out by many industries, the BTS Transportation Satellite Accounts (TSAs) are used. The TSAs measure the value of transportation services produced both by for-hire transportation industries and by other industries on own account (referred to as "in-house use" in the TSAs). These accounts are compiled using data on intermediate inputs specific to producing transportation services, combined with data on the employment of transportation employees (U.S. Bureau of Transportation Statistics, 2022). Emissions from trucking are attributed to industries in proportion to the value of truck transportation services produced (either for hire or on own account) by those industries.[15]

### iii. Bureau of Labor Statistics

The BLS Quarterly Census of Employment and Wages (QCEW) is conducted quarterly and provides data on employment by industry and by county, using records from each state's unemployment insurance program (U.S. Bureau of Labor Statistics, 2012). Each employer in a state submits quarterly reports with employment and wage data for each of their establishments within the state. The QCEW data are very disaggregated (in terms of industries). When other data sources are too aggregated, a second disaggregation and attribution step is performed using QCEW data to reach the desired level of industry aggregation. The implicit assumption when doing so is that employment is a reasonable proxy for industry size and emissions, especially when comparing closely related industries.

### iv. Energy Information Administration

EIA tracks energy use by manufacturing industries through the Manufacturing Energy Consumption Survey (MECS), published every 4 years (U.S. Energy Information Administration, 2018). MECS data are used to proportionally attribute methane and carbon dioxide emissions from coal and natural gas manufacturing and distillate fuel, hydrocarbon gas liquid, coke and breeze, natural gas, and other petroleum feedstocks to the appropriate industries.

### v. Private Data Providers

Data on the world average price of marine bunker fuel for ships were purchased form ShipandBunker.com. These data were used in combination with unpublished BEA data on marine fuel expenditures to estimate marine fuel usage and emissions for the marine shipping residency adjustment.

[15] This treatment of own-account production parallels the "before redefinition" treatment of secondary production. The "after redefinition" treatment reassigns secondary products to the industries *where they would have been* primary products, while the "before redefinition" treatment assign both primary and secondary products to the industries that actually produce them.

# 6. Tools

The data tables underlying the proof-of-concept U.S. *SEEA* air emissions account are generated in FLOWSA, a Python tool developed by EPA for attribution of environmental impacts to industries and non-business economic sectors such as households (Birney, et al., 2022). FLOWSA is open source[16] and allows for transparent and reproducible modeling of industry environmental impacts (including air emissions). The source data import process is automated, allowing models compiled in FLOWSA to be easily updated as new source data become available.

FLOWSA's operation can be summarized in three steps: (1) source data import, (2) activity to industry mapping, and (3) attributing environmental impacts, as found in the source data, to industries.

The first step in generating the air emissions account is to import datasets for all primary and secondary data sources. The source datasets are imported with the original terminology, units, and activities and formatted into standardized tables. These standardized tables simplify the process of harmonizing the data and allow for data sets that are used repeatedly to be used consistently each time. The most recent release of FLOWSA, v1.2.2, provides pre-imported tables for approximately 50 common environmental and economic data sources.

As the primary and secondary datasets are published with diverse terminology to describe activities, the second step is to create activity to industry mapping files that capture the relationship between the original dataset terminology (e.g., "Natural gas manufacturing") and industries, generally three- or four-digit NAICS codes. These crosswalks are created for each primary and secondary activity dataset and used to standardize industry terminology. The crosswalks do not capture how the data should be attributed, only which industries relate to each activity in a data source.

EPA provides crosswalks for datasets already imported into FLOWSA, but users may also define their own crosswalks. Crosswalks are developed using activity to industry mapping files provided by data publishers, through discussions with data publishers, and the definitions of source data activities and NAICS codes.

The final step of compiling the proof-of-concept air emissions account is building the industry attribution model and estimating the corresponding data tables. The model is represented by a unique methodology file instructing FLOWSA on which methods and secondary data sources to use in attributing the environmental impacts of each activity from the primary data source to industries.

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[16] Hosted on GitHub, at https://github.com/USEPA/flowsa

FLOWSA loads this methodology file and the impact-by-activity data table(s) from the primary data source. For each activity, FLOWSA uses the specified crosswalk, attribution method, and secondary data sources from the methodology file to attribute environmental impacts to industries, creating an impact-by-industry data table. The impact-by-industry data tables for each activity are then aggregated by industry to create a summary data table of impacts by industry, the primary output of FLOWSA.

The summary data tables of environmental impacts (in this case, greenhouse gas emissions) by industry generated by FLOWSA for each year are then formatted as supply-use tables. These tables, aggregated to the NAICS two-digit industry level, are found in the appendix.

# 7. Results

Physical supply and use tables for greenhouse gas emissions, covering the years 2012–2017, are found in appendices 1 (carbon dioxide equivalent units) and 2 (kilotons). Some interesting results are highlighted below.

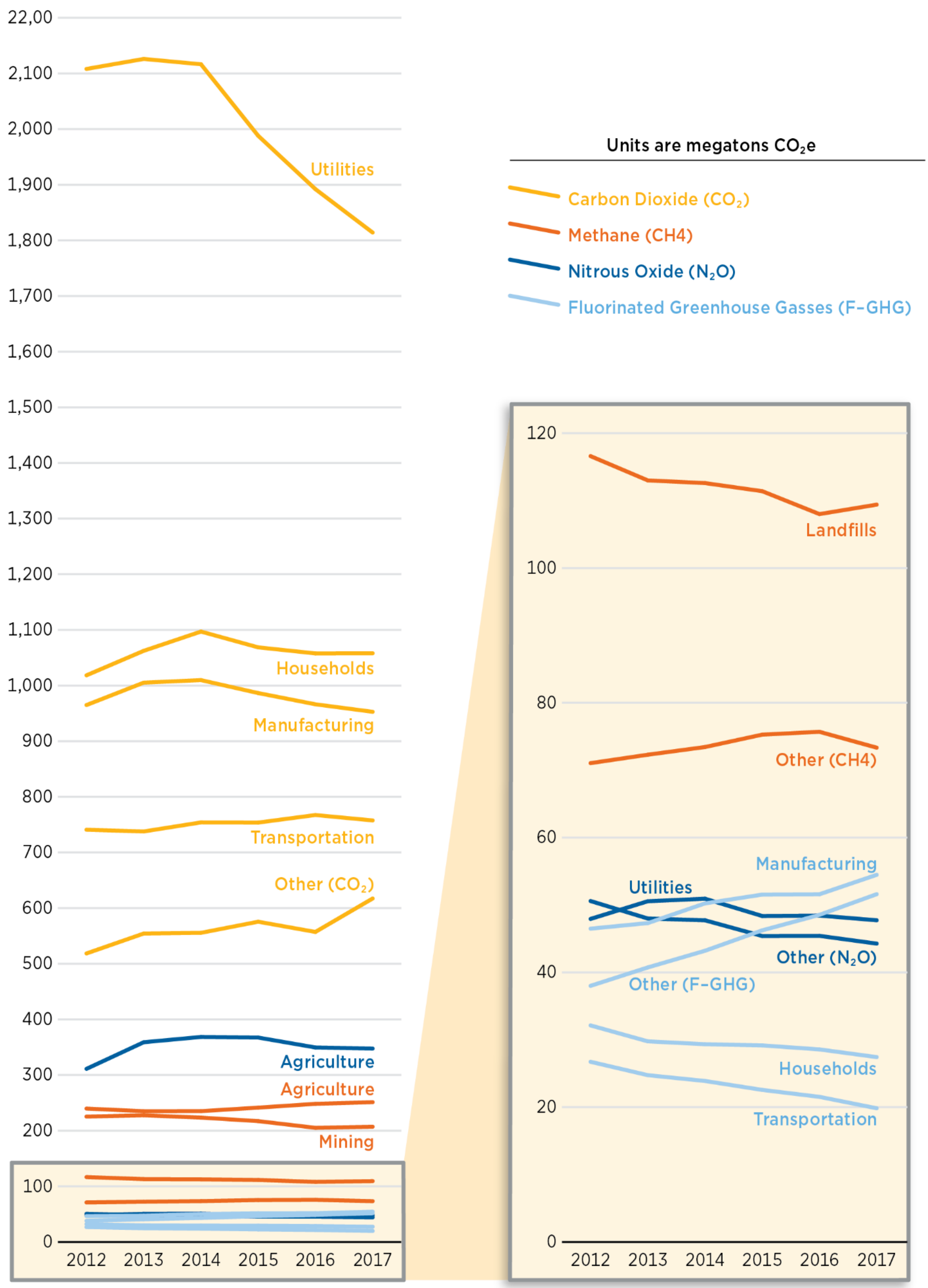
## A. Trends in Emissions by Major Emitters

Figure 2 shows trends in emissions of major greenhouse gas pollutants by major emitters.[17] Noticeable trends include:

- Decreased emissions of carbon dioxide by the utilities industry. This correlates with decreased use of coal and increased use of natural gas and renewable sources in electric power generation.
- Increased emissions of both nitrous oxide and methane emissions by the agriculture industry over this time period. This is consistent with findings that over the time period of this account, land used for cultivated crops increased (Wentland, et al., 2020), as did the number of cattle in the United States (USDA Economic Research Service, 2023).
- Decreased emissions of fluorinated greenhouse gases (F-GHGs) by two major emitters—transportation and households—roughly balanced out by increased emissions from other emitters, particularly manufacturing.

[17] Major emitters are defined here as industries/institutional sectors responsible for at least 10 percent of emissions of the gas in question.

**Figure 2. Trends in Emissions by Major Emitters**

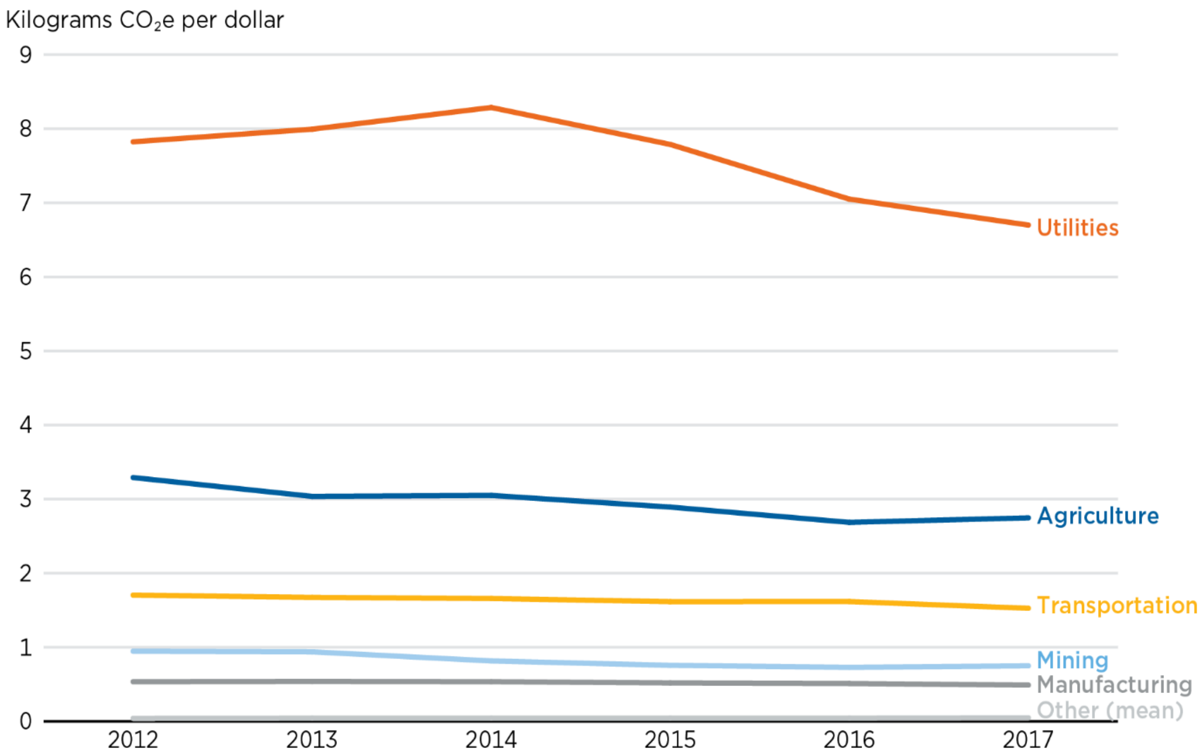


### B. Emissions Intensity per Dollar Value Added

Figure 3 shows trends in total greenhouse gas *emissions intensity*, or emissions (measured in kg carbon dioxide equivalent units) per dollar value added (dollar contributed to GDP). The first thing to notice in this figure is the wide variation of magnitudes across industries. Utilities (primarily due to electric generation) have by far the highest emissions intensity, double that of the next industry (agriculture).[18]

Only utilities, agriculture, and transportation have emissions per dollar value added greater than 1 kg $CO_2$e/dollar. Many other industries have emissions intensities a hundred or a thousand times smaller. Second, a slight, generally decreasing trend in emissions intensity is visible over the years covered by this account.

**Figure 3. Emissions per Dollar Value Added**

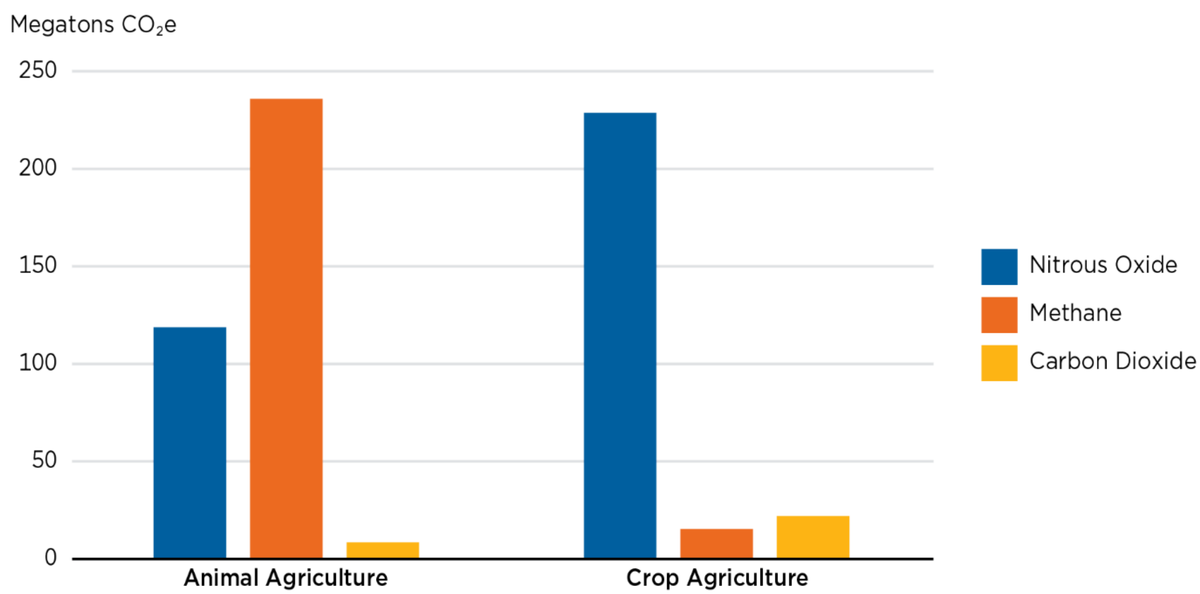



[18] It should be noted that dollars of value added cannot be considered a measure of an industry's true value to society. This is particularly true in the case of utilities, which are most commonly operating under heavily regulated prices, not at competitive market equilibria.

## C. Agricultural Emissions Breakdown

Figure 4 shows a breakdown of 2017 emissions within the agricultural sector. Due to their very different production processes, animal and crop agriculture have very different emissions profiles, as seen here. Animal agriculture produces significantly more total greenhouse gas emissions (in carbon dioxide equivalent units) than crop agriculture; ruminants (cattle) produce methane in digestion, while manure is a significant source of nitrous oxide emissions. Nitrous oxide emissions from crop agricultural land result in part from the application of nitrogen-containing fertilizers.

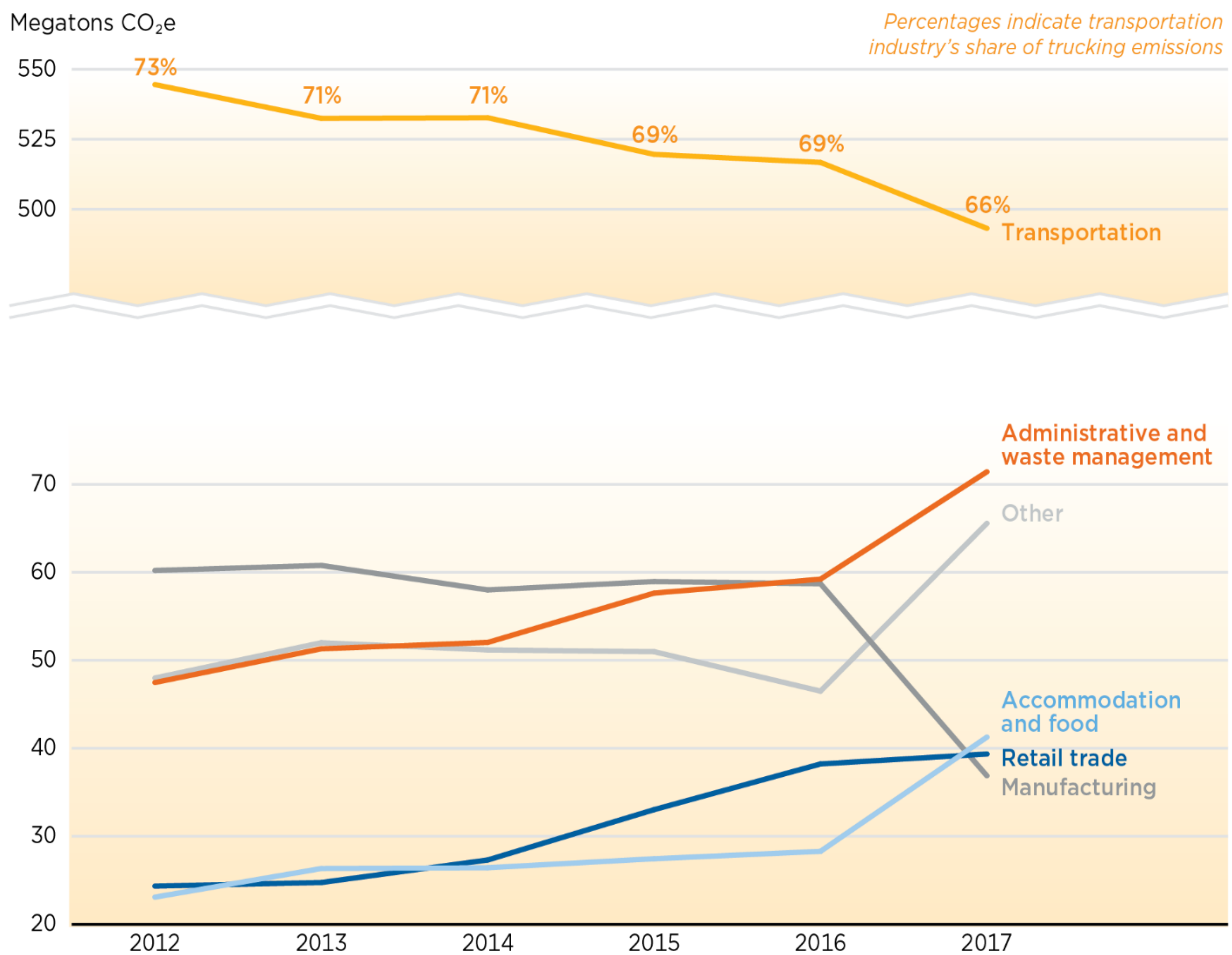
**Figure 4. 2017 Agricultural Emissions by Gas and Agriculture Type**



## D. Truck Transportation Activity Breakdown

Figure 5 shows total trucking emissions, broken down by industry. As shown here, between a quarter and a third of emissions from trucking are not produced by the truck transportation industry, but rather by businesses in other industries operating trucks for their own use. The share of emissions attributed to the truck transportation industry, while still around 2/3, has declined noticeably over the period covered by this account.

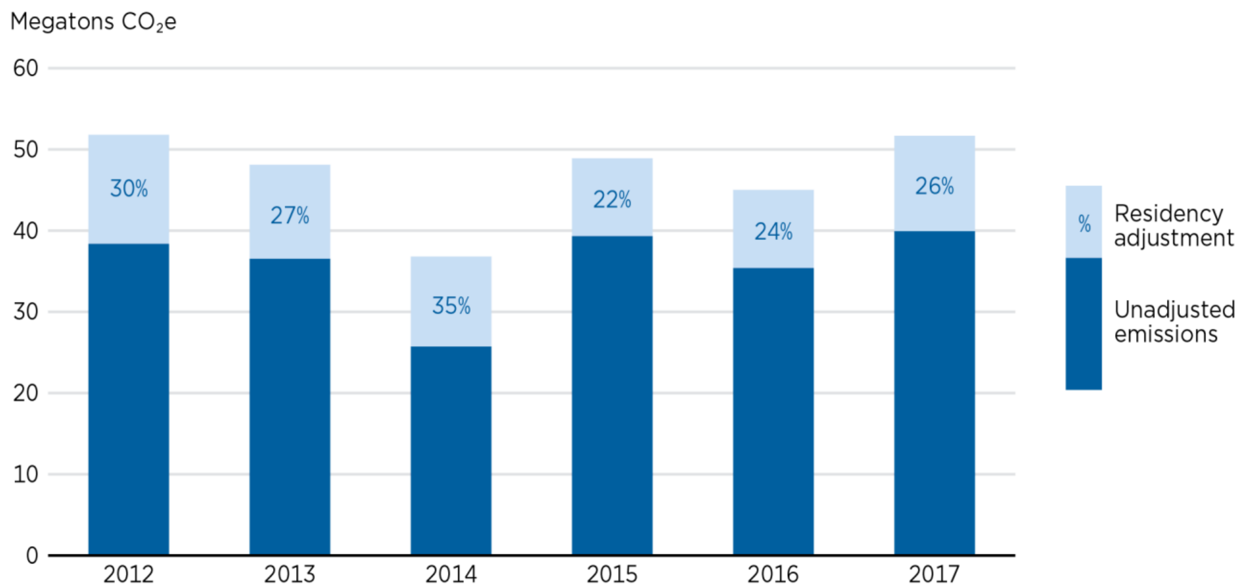
**Figure 5. Trucking Emissions by Industry**



### E. Water Transportation Residency Adjustment

Figure 6 shows a comparison of water transportation emissions before and after the residency adjustment is applied. The water transportation industry has the largest (percentagewise) residency adjustment among industries by far. The marine shipping component of the water transportation industry is the primary source of this adjustment since U.S.-operated ships on transoceanic routes will emit most of their emissions outside of U.S. territory.

**Figure 6. Water Transportation Emissions**



# 8. Challenges and Further Work

The biggest data gaps encountered in preparing a *SEEA*-consistent air emissions account for the United States lie in areas not adequately covered by the GHGI due to the difference between the territory basis of the GHGI and the residency basis of *SEEA*. The largest such gap is in marine transportation. It is known that ships burn a large quantity of fuel, producing a correspondingly large quantity of emissions. However, since these emissions are not included in the GHGI, they must be estimated directly, using data on fuel expenditures by U.S.-owned ships operating abroad and foreign owned ships operating in the United States, together with data on world average fuel prices. It would be preferable to have data on quantity of fuel consumed by U.S.-owned ships, like the data on fuel consumption by U.S. air carriers collected by BTS. However, BTS does not currently collect such data for ships.

A similar gap exists in truck transportation. U.S. trucks operate in Canada and Mexico, and Canadian and Mexican trucks operate in the United States. However, data on fuel consumed by U.S. trucks abroad, or Canadian and Mexican trucks in the United States, are not available. In this proof-of-concept account, the truck transportation residency adjustment is based on the ratio of truck transportation service imports and exports to domestic truck transportation output, but data on fuel consumption (again, like the BTS data on air carrier fuel consumption), would enable more accurate accounting for these emissions.

A gap not addressed in this account concerns the use of passenger cars by businesses. In this proof-of-concept account, all emissions from passenger cars are attributed to household consumption. Under *SEEA*, the emissions from cars operated by businesses should be attributed to the industries to which those businesses belong; further work on methodology and/or data sources is needed to make this attribution.

Further work on refining this account will include evaluating additional pollutants, such as fine particulate matter, for inclusion; searching for data to identify business use of passenger cars; and separating household emissions into heating, transportation, and other categories.

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# Appendix 1: Air Emissions Supply and Use Tables, 2012–2017, $CO_2$ Equivalent Units

### Table 1. 2012 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 37.25 | 112.85 | 2108.14 | 12.81 | 964.96 | 6.07 | 25.20 | 740.82 |
| **Methane** | 239.72 | 225.36 | 35.18 | 0.01 | 1.23 | 0.02 | 0.02 | 30.80 |
| **Nitrous Oxide** | 311.14 | 2.02 | 47.93 | 0.02 | 19.60 | 0.01 | 0.20 | 8.26 |
| **F-GHGs** | - | 0.95 | 0.06 | 1.20 | 46.49 | 3.18 | 2.83 | 26.73 |
| **Sulfur Hexaflouride** | - | - | 4.80 | - | 2.10 | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | 0.60 | - | - | - |
| **Total GWP** | 588.10 | 341.18 | 2196.12 | 14.04 | 1034.97 | 9.28 | 28.26 | 806.61 |

1. “Agriculture” includes forestry and fishing.

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 4.89 | 13.08 | 107.78 | 5.34 | 11.84 | 55.95 | 18.59 | 19.67 |
| **Methane** | 0.01 | 0.03 | 0.38 | 0.01 | 0.02 | 2.03 | 0.04 | 0.06 |
| **Nitrous Oxide** | 0.04 | 0.01 | 0.59 | 0.03 | 0.08 | 2.40 | 0.03 | 4.43 |
| **F-GHGs** | 4.87 | 0.14 | 0.66 | 2.75 | 0.50 | 5.79 | 0.62 | 4.98 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | - | - | - | - |
| **Total GWP** | 9.80 | 13.27 | 109.40 | 8.13 | 12.44 | 66.17 | 19.29 | 29.14 |

2. “Professional” includes scientific and technical services; “Administrative” includes support and waste management services.

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov’t | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 3.07 | 29.17 | 6.16 | 48.81 | - | 1018.39 | 5350.85 | 5350.85 | 5350.85 |
| **Methane** | 0.06 | 0.03 | 0.03 | - | 116.60 | 1.10 | 652.73 | 652.73 | 652.73 |
| **Nitrous Oxide** | 0.23 | 0.20 | 0.11 | 0.33 | - | 12.00 | 409.66 | 409.66 | 409.66 |
| **F-GHGs** | 0.35 | 4.91 | 1.90 | 2.30 | - | 32.13 | 143.36 | 143.36 | 143.36 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | 6.90 | 6.90 | 6.90 |
| **Nitrogen Triflouride** | - | - | - | - | - | - | 0.60 | 0.60 | 0.60 |
| **Total GWP** | 3.72 | 34.31 | 8.21 | 51.43 | 116.60 | 1063.62 | 6564.08 | 6564.08 | 6564.08 |

3. “Entertainment” includes art and recreation; “Hospitality” includes accommodation and food services; “Accumulations” represent emissions from decomposing waste.
4. All figures are reported in Mt CO2 equivalent (1 unit anywhere in the table represents global warming potential (GWP) equal to 1 megaton of carbon dioxide).

### Table 2. 2013 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 36.15 | 119.98 | 2126.08 | 13.23 | 1005.19 | 6.62 | 26.07 | 737.75 |
| Methane | 235.02 | 227.61 | 34.64 | 0.01 | 1.23 | 0.02 | 0.02 | 32.49 |
| Nitrous Oxide | 358.95 | 2.24 | 50.55 | 0.02 | 18.22 | 0.01 | 0.19 | 8.03 |
| F-GHGs | - | 0.94 | 0.06 | 1.31 | 47.31 | 3.45 | 2.92 | 24.75 |
| Sulfur Hexaflouride | - | - | 4.60 | - | 2.00 | - | - | - |
| Nitrogen Triflouride | - | - | - | - | 0.50 | - | - | - |
| Total GWP | 630.11 | 350.77 | 2215.93 | 14.58 | 1074.45 | 10.10 | 29.20 | 803.02 |

1. "Agriculture" includes forestry and fishing

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 5.07 | 14.60 | 122.69 | 5.71 | 12.10 | 60.64 | 21.34 | 21.97 |
| Methane | 0.01 | 0.03 | 0.38 | 0.01 | 0.01 | 2.23 | 0.04 | 0.06 |
| Nitrous Oxide | 0.03 | 0.01 | 0.59 | 0.04 | 0.08 | 2.50 | 0.04 | 4.44 |
| F-GHGs | 5.29 | 0.15 | 0.71 | 2.98 | 0.47 | 6.12 | 0.66 | 5.38 |
| Sulfur Hexaflouride | - | - | - | - | - | - | - | - |
| Nitrogen Triflouride | - | - | - | - | - | - | - | - |
| Total GWP | 10.39 | 14.80 | 124.36 | 8.73 | 12.66 | 71.49 | 22.08 | 31.85 |

2. "Professional" includes scientific and technical services; "Administrative" includes support and waste management services

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov't | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 3.87 | 33.10 | 6.85 | 44.35 | - | 1062.39 | 5485.74 | 5485.74 | 5485.74 |
| Methane | 0.07 | 0.03 | 0.03 | - | 113.00 | 1.00 | 647.93 | 647.93 | 647.93 |
| Nitrous Oxide | 0.23 | 0.21 | 0.11 | 0.29 | - | 10.70 | 457.49 | 457.49 | 457.49 |
| F-GHGs | 0.43 | 5.29 | 2.08 | 2.50 | - | 29.77 | 142.56 | 142.56 | 142.56 |
| Sulfur Hexaflouride | - | - | - | - | - | - | 6.60 | 6.60 | 6.60 |
| Nitrogen Triflouride | - | - | - | - | - | - | 0.50 | 0.50 | 0.50 |
| Total GWP | 4.60 | 38.63 | 9.07 | 47.14 | 113.00 | 1103.86 | 6740.82 | 6740.82 | 6740.82 |

3. "Entertainment" includes art and recreation; "Hospitality" includes accommodation and food services; "Accumulations" represent emissions from decomposing waste.
4. All figures are reported in Mt CO2 equivalent (1 unit anywhere in the table represents global warming potential (GWP) equal to 1 megaton of carbon dioxide).

### Table 3. 2014 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 32.72 | 111.68 | 2116.51 | 11.70 | 1009.73 | 6.64 | 29.69 | 754.00 |
| **Methane** | 235.12 | 223.50 | 34.39 | 0.01 | 1.22 | 0.02 | 0.02 | 33.78 |
| **Nitrous Oxide** | 368.44 | 1.93 | 50.93 | 0.02 | 19.73 | 0.01 | 0.21 | 8.01 |
| **F-GHGs** | - | 0.91 | 0.05 | 1.41 | 50.24 | 3.72 | 3.12 | 23.89 |
| **Sulfur Hexaflouride** | - | - | 4.90 | - | 1.60 | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | 0.50 | - | - | - |
| **Total GWP** | 636.27 | 338.01 | 2206.78 | 13.14 | 1083.02 | 10.39 | 33.03 | 819.67 |

**1.** "Agriculture" includes forestry and fishing

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 5.38 | 14.85 | 129.09 | 5.62 | 12.14 | 63.68 | 22.51 | 23.37 |
| **Methane** | 0.01 | 0.03 | 0.38 | 0.01 | 0.01 | 2.33 | 0.04 | 0.06 |
| **Nitrous Oxide** | 0.03 | 0.01 | 0.60 | 0.03 | 0.08 | 2.59 | 0.04 | 4.44 |
| **F-GHGs** | 5.68 | 0.16 | 0.75 | 3.20 | 0.44 | 6.35 | 0.69 | 5.77 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | - | - | - | - |
| **Total GWP** | 11.10 | 15.05 | 130.82 | 8.86 | 12.67 | 74.95 | 23.28 | 33.64 |

**2.** "Professional" includes scientific and technical services; "Administrative" includes support and waste management services

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov't | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 3.42 | 34.66 | 7.03 | 41.39 | - | 1096.97 | 5532.77 | 5532.77 | 5532.77 |
| **Methane** | 0.06 | 0.03 | 0.03 | - | 112.60 | 1.00 | 644.65 | 644.65 | 644.65 |
| **Nitrous Oxide** | 0.24 | 0.20 | 0.11 | 0.24 | - | 9.20 | 467.09 | 467.09 | 467.09 |
| **F-GHGs** | 0.47 | 5.57 | 2.24 | 2.70 | - | 29.34 | 146.68 | 146.68 | 146.68 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | 6.50 | 6.50 | 6.50 |
| **Nitrogen Triflouride** | - | - | - | - | - | - | 0.50 | 0.50 | 0.50 |
| **Total GWP** | 4.19 | 40.46 | 9.41 | 44.33 | 112.60 | 1136.51 | 6798.19 | 6798.19 | 6798.19 |

3. "Entertainment" includes art and recreation; "Hospitality" includes accommodation and food services; "Accumulations" represent emissions from decomposing waste.

4. All figures are reported in Mt CO2 equivalent (1 unit anywhere in the table represents global warming potential (GWP) equal to 1 megaton of carbon dioxide).

### Table 4. 2015 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 33.02 | 121.32 | 1988.02 | 11.70 | 986.46 | 8.74 | 35.77 | 753.69 |
| Methane | 241.42 | 217.17 | 34.47 | 0.01 | 1.32 | 0.02 | 0.02 | 35.59 |
| Nitrous Oxide | 367.34 | 1.70 | 48.36 | 0.02 | 19.10 | 0.02 | 0.23 | 7.56 |
| F-GHGs | - | 0.83 | 0.05 | 1.50 | 51.54 | 4.07 | 3.44 | 22.56 |
| Sulfur Hexaflouride | - | - | 3.80 | - | 1.70 | - | - | - |
| Nitrogen Triflouride | - | - | - | - | 0.60 | - | - | - |
| Total GWP | 641.77 | 341.03 | 2074.71 | 13.23 | 1060.72 | 12.85 | 39.46 | 819.40 |

1. “Agriculture” includes forestry and fishing.

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 6.19 | 16.69 | 122.19 | 6.14 | 11.41 | 70.31 | 21.91 | 25.87 |
| Methane | 0.01 | 0.04 | 0.38 | 0.01 | 0.01 | 2.33 | 0.04 | 0.07 |
| Nitrous Oxide | 0.03 | 0.02 | 0.59 | 0.03 | 0.06 | 2.60 | 0.04 | 4.44 |
| F-GHGs | 6.05 | 0.17 | 0.80 | 3.42 | 0.39 | 6.74 | 0.74 | 6.23 |
| Sulfur Hexaflouride | - | - | - | - | - | - | - | - |
| Nitrogen Triflouride | - | - | - | - | - | - | - | - |
| Total GWP | 12.28 | 16.92 | 123.97 | 9.60 | 11.88 | 81.99 | 22.74 | 36.61 |

2. “Professional” includes scientific and technical services; “Administrative” includes support and waste management services.

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov’t | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 3.94 | 36.77 | 8.03 | 35.55 | - | 1068.61 | 5372.32 | 5372.32 | 5372.32 |
| Methane | 0.07 | 0.04 | 0.04 | - | 111.40 | 0.80 | 645.27 | 645.27 | 645.27 |
| Nitrous Oxide | 0.23 | 0.20 | 0.12 | 0.19 | - | 8.20 | 461.10 | 461.10 | 461.10 |
| F-GHGs | 0.50 | 6.03 | 2.38 | 2.88 | - | 29.17 | 149.51 | 149.51 | 149.51 |
| Sulfur Hexaflouride | - | - | - | - | - | - | 5.50 | 5.50 | 5.50 |
| Nitrogen Triflouride | - | - | - | - | - | - | 0.60 | 0.60 | 0.60 |
| Total GWP | 4.74 | 43.03 | 10.57 | 38.61 | 111.40 | 1106.78 | 6634.29 | 6634.29 | 6634.29 |

3. “Entertainment” includes art and recreation; “Hospitality” includes accommodation and food services; “Accumulations” represent emissions from decomposing waste.
4. All figures are reported in Mt CO2 equivalent (1 unit anywhere in the table represents global warming potential (GWP) equal to 1 megaton of carbon dioxide).

### Table 5. 2016 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 32.36 | 103.95 | 1892.12 | 11.58 | 966.29 | 8.00 | 40.99 | 767.27 |
| **Methane** | 248.22 | 205.14 | 34.26 | 0.01 | 1.33 | 0.02 | 0.03 | 36.00 |
| **Nitrous Oxide** | 349.54 | 1.76 | 48.43 | 0.02 | 20.08 | 0.01 | 0.25 | 7.57 |
| **F-GHGs** | - | 0.65 | 0.03 | 1.60 | 51.59 | 4.36 | 3.69 | 21.53 |
| **Sulfur Hexaflouride** | - | - | 4.10 | - | 1.90 | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | 0.60 | - | - | - |
| **Total GWP** | 630.12 | 311.51 | 1978.94 | 13.20 | 1041.79 | 12.39 | 44.96 | 832.37 |

**1.** "Agriculture" includes forestry and fishing.

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 6.22 | 15.47 | 118.54 | 6.22 | 10.77 | 72.50 | 21.40 | 25.60 |
| **Methane** | 0.01 | 0.04 | 0.38 | 0.01 | 0.01 | 2.54 | 0.04 | 0.07 |
| **Nitrous Oxide** | 0.03 | 0.01 | 0.60 | 0.03 | 0.06 | 2.69 | 0.04 | 4.44 |
| **F-GHGs** | 6.41 | 0.17 | 0.85 | 3.64 | 0.35 | 6.95 | 0.79 | 6.61 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | - | - | - | - |
| **Total GWP** | 12.67 | 15.70 | 120.38 | 9.90 | 11.19 | 84.68 | 22.27 | 36.72 |

**2.** "Professional" includes scientific and technical services; "Administrative" includes support and waste management services.

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov't | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 3.62 | 37.42 | 7.52 | 35.00 | - | 1057.71 | 5240.56 | 5240.56 | 5240.56 |
| **Methane** | 0.06 | 0.04 | 0.04 | - | 108.00 | 0.80 | 637.06 | 637.06 | 637.06 |
| **Nitrous Oxide** | 0.24 | 0.19 | 0.11 | 0.19 | - | 7.10 | 443.39 | 443.39 | 443.39 |
| **F-GHGs** | 0.50 | 6.35 | 2.53 | 3.06 | - | 28.57 | 150.23 | 150.23 | 150.23 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | 6.00 | 6.00 | 6.00 |
| **Nitrogen Triflouride** | - | - | - | - | - | - | 0.60 | 0.60 | 0.60 |
| **Total GWP** | 4.42 | 44.00 | 10.20 | 38.25 | 108.00 | 1094.18 | 6477.84 | 6477.84 | 6477.84 |

3. "Entertainment" includes art and recreation; "Hospitality" includes accommodation and food services; "Accumulations" represent emissions from decomposing waste.
4. All figures are reported in Mt CO2 equivalent (1 unit anywhere in the table represents global warming potential (GWP) equal to 1 megaton of carbon dioxide).

### Table 6. 2017 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 32.24 | 114.86 | 1814.10 | 11.42 | 952.80 | 7.88 | 42.54 | 757.57 |
| **Methane** | 251.22 | 207.09 | 33.95 | 0.01 | 1.32 | 0.02 | 0.03 | 33.94 |
| **Nitrous Oxide** | 347.54 | 1.88 | 47.73 | 0.02 | 19.54 | 0.01 | 0.25 | 7.34 |
| **F-GHGs** | - | 0.79 | 0.05 | 1.66 | 54.47 | 4.56 | 3.74 | 19.84 |
| **Sulfur Hexaflouride** | - | - | 4.20 | - | 1.70 | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | 0.60 | - | - | - |
| **Total GWP** | 630.99 | 324.62 | 1900.03 | 13.12 | 1030.43 | 12.48 | 46.56 | 818.69 |

**1.** “Agriculture” includes forestry and fishing.

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 7.46 | 15.48 | 122.93 | 7.91 | 14.44 | 84.89 | 22.71 | 28.76 |
| **Methane** | 0.01 | 0.04 | 0.39 | 0.01 | 0.01 | 2.64 | 0.04 | 0.07 |
| **Nitrous Oxide** | 0.04 | 0.01 | 0.62 | 0.04 | 0.08 | 2.96 | 0.05 | 4.46 |
| **F-GHGs** | 6.70 | 0.18 | 0.98 | 3.83 | 0.46 | 7.42 | 0.85 | 6.97 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | - | - | - | - |
| **Total GWP** | 14.20 | 15.72 | 124.91 | 11.80 | 14.98 | 97.91 | 23.64 | 40.25 |

**2.** “Professional” includes scientific and technical services; “Administrative” includes support and waste management services.

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov’t | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 5.03 | 50.27 | 7.49 | 40.91 | - | 1057.97 | 5199.67 | 5199.67 | 5199.67 |
| **Methane** | 0.07 | 0.05 | 0.04 | - | 109.40 | 0.70 | 641.05 | 641.05 | 641.05 |
| **Nitrous Oxide** | 0.24 | 0.27 | 0.11 | 0.25 | - | 6.10 | 439.54 | 439.54 | 439.54 |
| **F-GHGs** | 0.61 | 6.98 | 2.64 | 3.19 | - | 27.43 | 153.34 | 153.34 | 153.34 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | 5.90 | 5.90 | 5.90 |
| **Nitrogen Triflouride** | - | - | - | - | - | - | 0.60 | 0.60 | 0.60 |
| **Total GWP** | 5.95 | 57.56 | 10.28 | 44.35 | 109.40 | 1092.20 | 6440.10 | 6440.10 | 6440.10 |

3. “Entertainment” includes art and recreation; “Hospitality” includes accommodation and food services; “Accumulations” represent emissions from decomposing waste
4. All figures are reported in Mt CO2 equivalent (1 unit anywhere in the table represents global warming potential (GWP) equal to 1 megaton of carbon dioxide.

# Appendix 2: Air Emissions Supply and Use Tables, 2012–2017, Kilotons

### Table 7. 2012 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 37250 | 112848 | 2108142 | 12806 | 964961 | 6072 | 25203 | 740817 |
| **Methane** | 9588.67 | 9014.41 | 1407.21 | 0.57 | 49.02 | 0.62 | 0.78 | 1232.09 |
| **Nitrous Oxide** | 1044.08 | 6.78 | 160.85 | 0.06 | 65.76 | 0.03 | 0.68 | 27.72 |
| **Sulfur Hexaflouride** | - | - | 0.21 | - | 0.09 | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | 0.03 | - | - | - |

1. “Agriculture” includes forestry and fishing.

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 4890 | 13081 | 107781 | 5340 | 11835 | 55950 | 18589 | 19669 |
| **Methane** | 0.20 | 1.32 | 15.04 | 0.23 | 0.75 | 81.13 | 1.58 | 2.33 |
| **Nitrous Oxide** | 0.12 | 0.04 | 1.97 | 0.12 | 0.28 | 8.04 | 0.12 | 14.87 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | - | - | - | - |

2. “Professional” includes scientific and technical services; “Administrative” includes support and waste management services.

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov’t | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 3074 | 29173 | 6161 | 48810 | - | 1018392 | 5350845 | 5350845 | 5350845 |
| **Methane** | 2.32 | 1.32 | 1.40 | - | 4664.00 | 44.00 | 26109.00 | 26109.00 | 26109.00 |
| **Nitrous Oxide** | 0.77 | 0.66 | 0.37 | 1.09 | - | 40.27 | 1374.69 | 1374.69 | 1374.69 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | 0.30 | 0.30 | 0.30 |
| **Nitrogen Triflouride** | - | - | - | - | - | - | 0.03 | 0.03 | 0.03 |

3. “Entertainment” includes art and recreation; “Hospitality” includes accommodation and food services; “Accumulations” represent emissions from decomposing waste.
4. All figures are reported in kt of the given gas (no adjustment made for global warming potential).

### Table 8. 2013 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 36150 | 119979 | 2126083 | 13233 | 1005194 | 6623 | 26070 | 737749 |
| **Methane** | 9400.67 | 9104.53 | 1385.52 | 0.57 | 49.03 | 0.62 | 0.78 | 1299.50 |
| **Nitrous Oxide** | 1204.52 | 7.52 | 169.65 | 0.07 | 61.14 | 0.03 | 0.65 | 26.96 |
| **Sulfur Hexaflouride** | - | - | 0.20 | - | 0.09 | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | 0.03 | - | - | - |

**1.** “Agriculture” includes forestry and fishing

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 5066 | 14599 | 122686 | 5706 | 12100 | 60637 | 21338 | 21967 |
| **Methane** | 0.20 | 1.32 | 15.04 | 0.23 | 0.41 | 89.19 | 1.59 | 2.35 |
| **Nitrous Oxide** | 0.11 | 0.04 | 1.97 | 0.12 | 0.28 | 8.39 | 0.13 | 14.89 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | - | - | - | - |

**2.** “Professional” includes scientific and technical services; “Administrative” includes support and waste management services.

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov’t | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 3873 | 33099 | 6851 | 44345 | - | 1062392 | 5485739 | 5485739 | 5485739 |
| **Methane** | 2.73 | 1.37 | 1.40 | - | 4520.00 | 40.00 | 25917.07 | 25917.07 | 25917.07 |
| **Nitrous Oxide** | 0.78 | 0.70 | 0.37 | 0.99 | - | 35.91 | 1535.21 | 1535.21 | 1535.21 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | 0.29 | 0.29 | 0.29 |
| **Nitrogen Triflouride** | - | - | - | - | - | - | 0.03 | 0.03 | 0.03 |

3. “Entertainment” includes art and recreation; “Hospitality” includes accommodation and food services; “Accumulations” represent emissions from decomposing waste.
4. All figures are reported in kt of the given gas (no adjustment made for global warming potential).

## Table 9. 2014 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 32719 | 111679 | 2116513 | 11698 | 1009727 | 6644 | 29687 | 753996 |
| Methane | 9404.67 | 8939.81 | 1375.49 | 0.57 | 48.99 | 0.62 | 0.83 | 1351.22 |
| Nitrous Oxide | 1236.36 | 6.46 | 170.91 | 0.06 | 66.22 | 0.03 | 0.69 | 26.87 |
| Sulfur Hexaflouride | - | - | 0.21 | - | 0.07 | - | - | - |
| Nitrogen Triflouride | - | - | - | - | 0.03 | - | - | - |

1. "Agriculture" includes forestry and fishing.

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 5380 | 14852 | 129085 | 5619 | 12140 | 63684 | 22512 | 23366 |
| Methane | 0.21 | 1.31 | 15.04 | 0.23 | 0.58 | 93.20 | 1.59 | 2.36 |
| Nitrous Oxide | 0.11 | 0.03 | 2.03 | 0.11 | 0.26 | 8.70 | 0.14 | 14.91 |
| Sulfur Hexaflouride | - | - | - | - | - | - | - | - |
| Nitrogen Triflouride | - | - | - | - | - | - | - | - |

2. "Professional" includes scientific and technical services; "Administrative" includes support and waste management services.

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov't | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 3419 | 34657 | 7029 | 41392 | - | 1096973 | 5532773 | 5532773 | 5532773 |
| Methane | 2.46 | 1.38 | 1.40 | - | 4504.00 | 40.00 | 25785.95 | 25785.95 | 25785.95 |
| Nitrous Oxide | 0.81 | 0.68 | 0.38 | 0.80 | - | 30.87 | 1567.43 | 1567.43 | 1567.43 |
| Sulfur Hexaflouride | - | - | - | - | - | - | 0.29 | 0.29 | 0.29 |
| Nitrogen Triflouride | - | - | - | - | - | - | 0.03 | 0.03 | 0.03 |

3. "Entertainment" includes art and recreation; "Hospitality" includes accommodation and food services; "Accumulations" represent emissions from decomposing waste.
4. All figures are reported in kt of the given gas (no adjustment made for global warming potential).

### Table 10. 2015 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 33019 | 121319 | 1988019 | 11698 | 986459 | 8740 | 35770 | 753693 |
| **Methane** | 9656.67 | 8687.00 | 1378.90 | 0.57 | 52.69 | 0.97 | 0.89 | 1423.58 |
| **Nitrous Oxide** | 1232.67 | 5.72 | 162.30 | 0.06 | 64.10 | 0.06 | 0.77 | 25.36 |
| **Sulfur Hexaflouride** | - | - | 0.17 | - | 0.07 | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | 0.03 | - | - | - |

**1.** "Agriculture" includes forestry and fishing.

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 6188 | 16685 | 122189 | 6141 | 11414 | 70313 | 21913 | 25868 |
| **Methane** | 0.27 | 1.68 | 15.36 | 0.34 | 0.44 | 93.21 | 1.64 | 2.69 |
| **Nitrous Oxide** | 0.12 | 0.07 | 1.99 | 0.11 | 0.21 | 8.73 | 0.14 | 14.91 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | - | - | - | - |

**2.** "Professional" includes scientific and technical services; "Administrative" includes support and waste management services.

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov't | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 3936 | 36766 | 8029 | 35545 | - | 1068614 | 5372318 | 5372318 | 5372318 |
| **Methane** | 2.65 | 1.54 | 1.60 | - | 4456.00 | 32.00 | 25810.68 | 25810.68 | 25810.68 |
| **Nitrous Oxide** | 0.78 | 0.67 | 0.39 | 0.63 | - | 27.52 | 1547.31 | 1547.31 | 1547.31 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | 0.24 | 0.24 | 0.24 |
| **Nitrogen Triflouride** | - | - | - | - | - | - | 0.03 | 0.03 | 0.03 |

3. "Entertainment" includes art and recreation; "Hospitality" includes accommodation and food services; "Accumulations" represent emissions from decomposing waste.
4. All figures are reported in kt of the given gas (no adjustment made for global warming potential).

### Table 11. 2016 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 32362 | 103952 | 1892119 | 11576 | 966287 | 8003 | 40992 | 767271 |
| **Methane** | 9928.67 | 8205.79 | 1370.37 | 0.57 | 53.00 | 0.97 | 1.15 | 1439.98 |
| **Nitrous Oxide** | 1172.94 | 5.90 | 162.51 | 0.06 | 67.40 | 0.03 | 0.84 | 25.39 |
| **Sulfur Hexaflouride** | - | - | 0.18 | - | 0.08 | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | 0.03 | - | - | - |

**1.** “Agriculture” includes forestry and fishing.

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 6223 | 15471 | 118540 | 6220 | 10772 | 72502 | 21402 | 25600 |
| **Methane** | 0.29 | 1.68 | 15.37 | 0.36 | 0.47 | 101.54 | 1.66 | 2.76 |
| **Nitrous Oxide** | 0.11 | 0.03 | 2.03 | 0.10 | 0.19 | 9.03 | 0.13 | 14.90 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | - | - |
| **Nitrogen Triflouride** | - | - | - | - | - | - | - | - |

**2.** “Professional” includes scientific and technical services; “Administrative” includes support and waste management services.

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov’t | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| **Carbon Dioxide** | 3623 | 37422 | 7516 | 34998 | - | 1057713 | 5240563 | 5240563 | 5240563 |
| **Methane** | 2.45 | 1.67 | 1.60 | - | 4320.00 | 32.00 | 25482.37 | 25482.37 | 25482.37 |
| **Nitrous Oxide** | 0.79 | 0.64 | 0.38 | 0.65 | - | 23.83 | 1487.87 | 1487.87 | 1487.87 |
| **Sulfur Hexaflouride** | - | - | - | - | - | - | 0.26 | 0.26 | 0.26 |
| **Nitrogen Triflouride** | - | - | - | - | - | - | 0.03 | 0.03 | 0.03 |

3. “Entertainment” includes art and recreation; “Hospitality” includes accommodation and food services; “Accumulations” represent emissions from decomposing waste
4. All figures are reported in kt of the given gas (no adjustment made for global warming potential).

### Table 12. 2017 Physical Supply and Use of Air Emissions in the U.S., at NAICS 2-Digit Level

| Pollutant\Industry | Agriculture[1] | Mining | Utilities | Construction | Manufacturing | Wholesale | Retail | Transportation |
|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 32240 | 114864 | 1814105 | 11423 | 952801 | 7883 | 42537 | 757571 |
| Methane | 10048.67 | 8283.53 | 1357.92 | 0.57 | 52.65 | 0.97 | 1.17 | 1357.65 |
| Nitrous Oxide | 1166.23 | 6.32 | 160.17 | 0.06 | 65.56 | 0.03 | 0.85 | 24.64 |
| Sulfur Hexaflouride | - | - | 0.18 | - | 0.07 | - | - | - |
| Nitrogen Triflouride | - | - | - | - | 0.03 | - | - | - |

1. "Agriculture" includes forestry and fishing.

| Pollutant\Industry | Information | Finance | Real Estate | Professional[2] | Management | Administrative[2] | Education | Health Care |
|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 7456 | 15485 | 122926 | 7912 | 14435 | 84890 | 22707 | 28759 |
| Methane | 0.31 | 1.68 | 15.41 | 0.38 | 0.53 | 105.73 | 1.69 | 2.81 |
| Nitrous Oxide | 0.13 | 0.03 | 2.09 | 0.14 | 0.26 | 9.93 | 0.15 | 14.96 |
| Sulfur Hexaflouride | - | - | - | - | - | - | - | - |
| Nitrogen Triflouride | - | - | - | - | - | - | - | - |

2. "Professional" includes scientific and technical services; "Administrative" includes support and waste management services.

| Pollutant\Industry | Entertainment[3] | Hospitality[3] | Oth. Services | Gov't | Acc.[3] | Households | Tot. Supply | Environment | Total Use |
|---|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 5027 | 50270 | 7490 | 40913 | - | 1057973 | 5199667 | 5199667 | 5199667 |
| Methane | 2.78 | 1.89 | 1.60 | - | 4376.00 | 28.00 | 25641.96 | 25641.96 | 25641.96 |
| Nitrous Oxide | 0.81 | 0.90 | 0.38 | 0.84 | - | 20.47 | 1474.96 | 1474.96 | 1474.96 |
| Sulfur Hexaflouride | - | - | - | - | - | - | 0.26 | 0.26 | 0.26 |
| Nitrogen Triflouride | - | - | - | - | - | - | 0.03 | 0.03 | 0.03 |

3. "Entertainment" includes art and recreation; "Hospitality" includes accommodation and food services; "Accumulations" represent emissions from decomposing waste.
4. All figures are reported in kt of the given gas (no adjustment made for global warming potential).