



Greenhouse Gas Inventory Guidance

# Direct Emissions from Mobile Combustion Sources



January 2016

---

---

The U.S. EPA Center for Corporate Climate Leadership’s (The Center) GHG guidance is based on The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (GHG Protocol) developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The Center’s GHG guidance is meant to extend upon the GHG Protocol to align more closely with EPA-specific GHG calculation methodologies and emission factors, and to support the Center’s GHG management tools and its Climate Leadership Awards initiative.

For more information regarding the Center for Corporate Climate Leadership, visit [www.epa.gov/climateleadership](http://www.epa.gov/climateleadership).

# Table of Contents

Section 1: Introduction .....	1
1.1. Scope 1 versus Scope 3 Mobile Source Emissions .....	2
1.2. Greenhouse Gases Included.....	2
1.3. Biofuels .....	3
Section 2: Calculating CO <sub>2</sub> Emissions .....	4
Section 3: Calculating CH <sub>4</sub> and N <sub>2</sub> O Emissions .....	6
Section 4: Choice of Activity Data and Emission Factors .....	7
4.1. Activity Data.....	7
4.2. Fuel Carbon Content and Heat Content.....	9
4.3. Emission Factors .....	10
Section 5: Completeness .....	11
Section 6: Uncertainty Assessment.....	12
Section 7: Documentation.....	13
Section 8: Inventory Quality Assurance and Quality Control (QA/QC).....	14
Appendix A: Default CO <sub>2</sub> Emission Factors.....	15
Appendix B: Default CH <sub>4</sub> and N <sub>2</sub> O Emission Factors .....	17

## Section 1: Introduction

Greenhouse gas (GHG) emissions are produced by mobile sources as fuels are burned. Carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O) are emitted directly through the combustion of fuels in different types of mobile equipment. A list of mobile sources that could potentially be included in an organization's GHG inventory is provided in Table 1. GHG emissions from mobile sources also include hydrofluorocarbon (HFC) and perfluorocarbon (PFC) emissions from mobile air conditioning and transport refrigeration leaks. The calculation of fugitive HFC and PFC emissions from mobile sources is described in the Center's guidance for Direct Fugitive Emissions from Refrigeration, Air Conditioning, Fire Suppression, and Industrial Gases.

<b>Category</b>	<b>Primary Fuels Used</b>
On-road Vehicles	
— Passenger Cars	Gasoline
— Vans, Pickup Trucks & SUVs	Diesel Fuel
— Heavy-Duty Vehicles	
— Combination Trucks	
— Buses	
Non-Road Vehicles	
— Construction Equipment	Diesel Fuel
— Agricultural Equipment	Gasoline
— Forklifts	
— Other Non-Road Equipment	
Waterborne	
— Ships	Diesel Fuel
— Boats	Residual Fuel Oil
	Gasoline
Rail	
— Freight Trains	Diesel Fuel
— Commuter Rail	Electric
— Amtrak	
Air	
— Commercial Aircraft	Kerosene Jet Fuel
— Executive Jets	

## 1.1. Scope 1 versus Scope 3 Mobile Source Emissions

This document presents the guidance for calculating scope 1 direct GHG emissions resulting from the operation of owned or leased mobile sources that are within an organization's inventory boundary. This guidance applies to all sectors whose operations include owned or leased mobile sources.

All other organization-related mobile source emissions, including employee commuting, employee travel, and upstream/downstream third-party transportation emissions, such as those associated with transporting material inputs or product distribution, are considered scope 3 indirect emissions. This guidance document focuses on scope 1 emissions. While some of the approaches in this document can also apply to scope 3 sources, organizations should refer to the separate scope 3 guidance document for specific approaches to calculate scope 3 mobile source emissions.

Furthermore, this guidance focuses on accounting for emissions resulting directly from an organization's activities, not on the full life cycle greenhouse gas emissions associated with those activities. For example, a fleet owner would use this guidance to account for emissions resulting from fleet fuel usage, but not for the emissions associated with producing the fuel.

Users of this guidance should be aware, however, that the choice of transportation modes and fuels can greatly influence GHG emissions from a life cycle perspective. A transportation mode may have relatively few GHG emissions from the vehicle itself, but emissions could be higher from the production of the fuel.

## 1.2. Greenhouse Gases Included

The greenhouse gases CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O are emitted during the combustion of fuels in mobile sources. For most transportation modes, CH<sub>4</sub> and N<sub>2</sub>O emissions comprise a relatively small proportion of overall transportation-related GHG emissions (approximately one percent combined).<sup>1</sup> For on-road vehicles less than 15 years old, CH<sub>4</sub> and N<sub>2</sub>O emissions typically account for one percent of emissions or less. However, for older gasoline fueled on-road vehicles, CH<sub>4</sub> and N<sub>2</sub>O could be a more significant (approximately five percent) portion of total GHG emissions. CH<sub>4</sub> and N<sub>2</sub>O emissions are typically an even higher percentage of total GHG emissions from non-road or alternative fuel vehicles.

Organizations should account for all CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions associated with mobile combustion. Given the relative emissions contributions of each gas, CH<sub>4</sub> and N<sub>2</sub>O emissions are sometimes excluded by assuming that they are not material. However, as outlined in Chapter 1 of the GHG Protocol, the materiality of a source can only be established after it has been assessed. This assessment does not necessarily require a rigorous quantification of all sources, but at a minimum, an estimate based on available data should be developed for all sources and categories of GHGs, and included in an organization's GHG inventory.

Information on methods used to calculate CO<sub>2</sub> emissions is found in Section 2. Information on an approach for determining CH<sub>4</sub> and N<sub>2</sub>O emissions is found in Section 3. The approach to calculating CO<sub>2</sub> emissions from mobile combustion sources varies significantly from the approach to calculating CH<sub>4</sub> and N<sub>2</sub>O emissions. While CO<sub>2</sub> can be

---

<sup>1</sup> See Table 3-7 of U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013, EPA 430-R-15-003, April 2015 .

reasonably calculated by applying emission factors based on the fuel quantity consumed, CH<sub>4</sub> and N<sub>2</sub>O emissions depend largely on the emissions control equipment used (e.g., type of catalytic converter) and vehicle miles traveled. Emissions of these gases also vary with the efficiency and vintage of the combustion technology, as well as maintenance and operational practices. Due to this complexity, a much higher level of uncertainty exists in the calculation of CH<sub>4</sub> and N<sub>2</sub>O emissions from mobile combustion sources, compared to the calculation of CO<sub>2</sub> emissions.

### 1.3. Biofuels

Not all mobile combustion sources burn fossil fuels. Biomass (non-fossil) fuels (e.g., ethanol, biodiesel) may be combusted in mobile sources independently or co-fired with fossil fuels. The emission calculation methods discussed in this document can be used to calculate CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions from combustion of these fuels. The GHG Protocol requires that CO<sub>2</sub> emissions from biomass combustion for mobile sources are reported as biomass CO<sub>2</sub> emissions (in terms of total amount of biogenic CO<sub>2</sub>) and are tracked separately from fossil CO<sub>2</sub> emissions. Biomass CO<sub>2</sub> emissions are not included in the overall CO<sub>2</sub>-equivalent emissions inventory for organizations following this guidance. CH<sub>4</sub> and N<sub>2</sub>O emissions from biofuels are included in the overall CO<sub>2</sub>-equivalent emissions inventory.

There are several transportation fuels that are actually blends of fossil and non-fossil fuels. For example, E85 is an ethanol (biomass fuel) and gasoline (fossil fuel) blend containing 51 percent to 83 percent ethanol, and B20 is a blend of 20 percent biodiesel (biomass fuel) and 80 percent diesel fuel (fossil fuel). The majority of motor gasoline used in the United States is made up of a blend of gasoline and ethanol. Typically, the blend is E10 (10 percent ethanol and 90 percent gasoline), but the content of ethanol in gasoline varies by location and by year. Combustion of these blended fuels results in emissions of both fossil CO<sub>2</sub> and biomass CO<sub>2</sub>. Organizations should report both types of CO<sub>2</sub> emissions if blended fuels are used.

The blend percentage can be used to estimate the quantity of fossil fuel and biofuel. For example, if the organization consumes 1,000 gallons of E10, that can be treated as 100 gallons of ethanol and 900 gallons of gasoline. Separate fossil and biomass emission factors can then be applied to this mix of fuels. If an organization lacks specific biofuel content data, the organization may assume 10 percent ethanol for gasoline and may use the national average ethanol content for E85. This is reported in the U.S. EIA's Annual Energy Outlook, and is currently 74 percent.

An organization may operate "flex-fuel" vehicles, which can use either fossil fuels or a biofuel blend. If the organization is uncertain which fuel is used in these vehicles, fossil fuel should be assumed.

Recently, there has been increased scientific inquiry into accounting for biomass in energy production. The EPA's Science Advisory Board recently found that "there are circumstances in which biomass is grown, harvested and combusted in a carbon neutral fashion but carbon neutrality is not an appropriate a priori assumption; it is a conclusion that should be reached only after considering a particular feedstock's production and consumption cycle. There is considerable heterogeneity in feedstock types, sources and production methods and thus net biogenic carbon emissions will vary considerably."<sup>2</sup> According to the GHG Protocol Corporate Standard, "consensus methods have yet to be developed under the GHG Protocol Corporate Standard for accounting of sequestered atmospheric carbon as it moves through the value chain of biomass based industries," though some general considerations for accounting for sequestered atmospheric carbon are discussed in Chapter 9 and Appendix B of the GHG Protocol Corporate Standard.

---

<sup>2</sup>EPA Science Advisory Board Review of the 2011 Draft Accounting Framework for CO<sub>2</sub> Emissions for Biogenic Sources Study. 2012.

<http://www.epa.gov/climatechange/ghgemissions/biogenic-emissions.html>

## Section 2: Calculating CO<sub>2</sub> Emissions

The CO<sub>2</sub> emissions associated with fuel combustion are a function of the volume of fuel combusted, the density of the fuel, the carbon content of the fuel, and the fraction of carbon that is oxidized to CO<sub>2</sub>. One of three equations can be used to calculate CO<sub>2</sub> emissions for each type of fuel combusted. The appropriate equation to use depends on what is known about the characteristics of the fuel being consumed.

Equation 1 is recommended when fuel consumption is known only in mass or volume units, and no information is available about the fuel heat content or carbon content. This equation is the least preferred. It has the most uncertainty because its emission factors are based on default fuel heat content, rather than actual heat content.

### Equation 2:

$$\text{Emissions} = \text{Fuel} \times \text{HHV} \times \text{EF}_2$$

Where:

$$\text{Emissions} = \text{Mass of CO}_2 \text{ emitted}$$

$$\text{Fuel} = \text{Mass or volume of fuel combusted}$$

HHV = Fuel heat content (higher heating value), in units of energy per mass or volume of fuel

$$\text{EF}_2 = \text{CO}_2 \text{ emission factor per energy unit}$$

Equation 3 is recommended to calculate CO<sub>2</sub> emissions when the actual carbon content of the fuel is known. Carbon content is typically expressed as a percentage by mass, which requires fuel use data in mass units. This equation is most preferred for CO<sub>2</sub> calculations because CO<sub>2</sub> emissions are directly related to the fuel's carbon content.

Follow the steps below to calculate emissions.

### Step 1: Select the appropriate equation.

Based on the information available on the characteristics of the fuel being consumed, select the appropriate equation to use in calculating emissions. See the discussion above on the three possible equations.

### Equation 1:

$$\text{Emissions} = \text{Fuel} \times \text{EF}_1$$

Where:

$$\text{Emissions} = \text{Mass of CO}_2 \text{ emitted}$$

Fuel = Mass or volume of fuel combusted

EF<sub>1</sub> = CO<sub>2</sub> emission factor per mass or volume unit

Equation 2 is recommended when the actual fuel heat content is provided by the fuel supplier or is otherwise known. In such cases, the fuel use in energy units can be multiplied directly by the emission factor (EF<sub>2</sub>). Equation 2 is a preferable approach over Equation 1 because it uses emission factors that are based on energy units as opposed to mass or volume units. Emission factors based on energy units are less variable than factors per mass or volume units because the carbon content of a fuel is more closely related to the heat content of the fuel than to the total physical quantity of fuel.

### Equation 3:

$$\text{Emissions} = \text{Fuel} \times \text{CC} \times 44/12$$

Where:

$$\text{Emissions} = \text{Mass of CO}_2 \text{ emitted}$$

Fuel = Mass or volume of fuel combusted

CC = Fuel carbon content, in units of mass of carbon per mass or volume of fuel

44/12 = ratio of molecular weights of CO<sub>2</sub> and carbon

**Step 2: Determine the amount of fuel combusted.**

Each fuel type should be quantified separately. This can be based on fuel receipts or purchase records. Methods for determining fuel use are discussed in Section 4.1.

**Step 3: Determine equation inputs.**

The selected equation specifies which inputs are needed to calculate emissions. As appropriate, determine the fuel carbon content, fuel heat content, and/or emission factors associated with each fuel consumed. Further guidance is given in Section 4, and emission factors are provided in Appendix A.

**Step 4: Calculate emissions.**

Use the appropriate equation with the fuel consumption and other equation inputs to calculate the emissions of CO<sub>2</sub>.

The EPA SmartWay Transport Partnership (SmartWay) has various tools on its website that allow an organization to calculate CO<sub>2</sub> emissions for their mobile source fleet. If the organization has more detailed information on the vehicle models and fuel type, it may elect to use the tools available on the SmartWay website (<http://www.epa.gov/smartway/>) instead of using the default values for CO<sub>2</sub> emission factors in this document. Organizations that choose to use EPA's SmartWay tools should include the specific data and factors used in their Inventory Management Plan (IMP).



## Section 3: Calculating CH<sub>4</sub> and N<sub>2</sub>O Emissions

One of two equations can be used to calculate CH<sub>4</sub> and N<sub>2</sub>O emissions for each type of fuel combusted. Equation 4 is applicable to on-road vehicles such as cars, trucks, and buses. Equation 5 is applicable to non-road vehicles such as construction or agricultural equipment, forklifts, ships, boats, rail vehicles, or aircraft.

### Equation 4:

$$\text{Emissions} = \text{Distance} \times \text{EF}_4$$

Where:

Emissions = Mass of CH<sub>4</sub> or N<sub>2</sub>O emitted

Distance = Vehicle distance traveled

EF<sub>4</sub> = CH<sub>4</sub> or N<sub>2</sub>O emission factor per distance unit

### Equation 5:

$$\text{Emissions} = \text{Fuel} \times \text{EF}_5$$

Where:

Emissions = Mass of CH<sub>4</sub> or N<sub>2</sub>O emitted

Fuel = Volume of fuel combusted

EF<sub>5</sub> = CH<sub>4</sub> or N<sub>2</sub>O emission factor per volume unit

Follow the steps below to calculate emissions.

### Step 1: Select appropriate equation.

As discussed further above, Equation 4 is applicable to on-road vehicles and Equation 5 is applicable to non-road vehicles.

### Step 2: Determine the distance traveled or the amount of fuel combusted.

For road vehicles, gather data on the distance traveled, which is typically obtained from odometer readings. For non-road vehicles, gather data on the volume of fuel combusted, which is typically obtained from fuel purchase records. Methods for determining distance and fuel use are discussed in Section 4.1.

### Step 3: Determine emission factors.

The selected equation specifies the appropriate emission factors to be used. Further guidance is given in Section 4.3, and emission factors are provided in Appendix B.

### Step 4: Calculate emissions.

Use the appropriate equation with the distance or fuel consumption and the appropriate emission factors to calculate the emissions of CH<sub>4</sub> and N<sub>2</sub>O. Multiply the emissions of CH<sub>4</sub> and N<sub>2</sub>O by the respective global warming potential (GWP) to calculate CO<sub>2</sub>-equivalent emissions. The GWPs are 25 for CH<sub>4</sub> and 298 for N<sub>2</sub>O, from the Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (AR4), 2007. Sum the CO<sub>2</sub> equivalent emissions from CH<sub>4</sub> and N<sub>2</sub>O with the emissions of CO<sub>2</sub> to calculate the total CO<sub>2</sub>-equivalent (CO<sub>2</sub>e) emissions.

# Section 4: Choice of Activity Data and Emission Factors

## 4.1. Activity Data

To maximize the accuracy of emissions calculations, it is useful to have as much information as possible about the organization's vehicles. Ideally, a list of vehicles would be created with the following information provided for each vehicle:

- Fuel type
- Fuel use
- Distance traveled (for on-road vehicles)
- Fuel economy (if either fuel use or distance traveled is unavailable)
- Vehicle type
- Emissions control technology and/or model year

If vehicle-specific information is not available, the calculation methods can be applied to subtotaled fuel use data by fuel type, and to subtotaled distance data by vehicle type and model year.

This section provides guidance on fuel use data, distance data, and fuel economy. When calculating CO<sub>2</sub> emissions, and when calculating CH<sub>4</sub> and N<sub>2</sub>O emissions from non-road vehicles, the activity data that need to be gathered is the quantity of fuel combusted for each fuel type. When calculating CH<sub>4</sub> and N<sub>2</sub>O emissions from on-road vehicles, the activity data needed is the distance traveled. These emissions also depend on vehicle type and control technology or model year, which are discussed in Appendix B.

The most accurate method of determining the amount of fuel combusted, and therefore the preferred method, is to gather data from fuel receipts or purchase records. If fuel is purchased at commercial fueling stations, fuel receipts can typically be obtained from the vehicle operators, or through records from centralized fuel card services. If fuel is delivered to the organization's facilities either to fill on-site fuel storage or to fill vehicles directly, fuel use can be determined through delivery records or fuel invoices. If natural gas vehicles are fueled on-site, fuel purchase data can be obtained from monthly natural gas bills. If a particular fuel type is used for both stationary and mobile sources, care should be taken to avoid double-counting the fuel use.

If purchase records are used, several factors could lead to differences between the amount of fuel purchased and the amount of fuel actually combusted during a reporting period. These factors can include changes in fuel storage inventory, fugitive releases, or fuel spills.

For changes in fuel storage inventory, Equation 6 can be used to calculate actual fuel use.

Fuel purchase data are usually reported as the amount of fuel provided by a supplier as it crosses the gate of the facility. However, once fuel enters the facility there could be some losses before it actually is combusted. Before calculating emissions, organizations should subtract the amount of fuel lost in fugitive releases or spills from the amount of fuel purchased. These losses are particularly important for natural gas, which could be lost due to fugitive releases from facility valves and piping, as these fugitive emissions could be significant. These fugitive natural gas releases (essentially methane emissions) should be accounted for separately from combustion emissions.

#### **Equation 6: Accounting for Changes in Fuel Inventory**

$$\text{Fuel B} = \text{Fuel P} + (\text{Fuel } S_{\text{T}} - \text{Fuel } S_{\text{E}})$$

Where:

Fuel B = Fuel burned in reporting period

Fuel P = Fuel purchased in reporting period

Fuel  $S_{\text{T}}$  = Fuel stock at start of reporting period

Fuel  $S_{\text{E}}$  = Fuel stock at end of reporting period

It is possible that organizations may only know the dollar amount spent on a type of fuel. This is the least accurate method of determining fuel use and is not recommended for GHG reporting. If the amount spent on fuel is the only information initially available, it is recommended that organizations contact their fuel supplier to request data in physical or energy units. If absolutely no other information is available, organizations should use fuel prices to convert the amount spent to physical or energy units, and should document the prices used. Price varies widely for specific fuels, especially over the geographic area and timeframe typically established for reporting GHG emissions.

For on-road vehicles, distance traveled data are also required in addition to fuel use. This distance should be tracked in units of vehicle-miles or vehicle-kilometers, as opposed to passenger-miles or passenger-kilometers, which are often used for scope 3 mobile source emissions. Distance data are best obtained from vehicle odometer readings. These could be provided from the vehicle operators or from vehicle maintenance records. If a centralized fuel card service is used, odometer readings may be required to be entered when fuel is purchased, in which case the odometer readings are typically available from fuel card records. In the absence of distance data for a specific year, a reasonable approximation of annual distance traveled can be made by dividing a vehicle's current odometer reading by the number of years it has been operating.

CO<sub>2</sub> emissions, and CH<sub>4</sub>, and N<sub>2</sub>O emissions for non-road vehicles should be calculated using actual fuel use data. CH<sub>4</sub> and N<sub>2</sub>O emissions for on-road vehicles should be calculated using actual distance traveled data. These approaches are especially recommended if emissions from mobile sources are a significant component of an organization's total GHG inventory. If accurate records of either fuel use or distance traveled are not available, the missing data can be estimated using fuel economy factors. For example, if fuel use in gallons is known, this can be multiplied by fuel economy in miles per gallon to obtain miles traveled. If distance traveled in miles is known, this can be divided by fuel economy in miles per gallon to obtain gallons of fuel use. Estimating fuel use with fuel economy factors is not as preferable as directly obtaining fuel use data, with the exception of fuel data based on the dollar amount spent on fuel. If accurate data are known on distance traveled and fuel economy for specific vehicle types, this method is preferred over using fuel price data.

The preferred method for determining fuel economy for on-road vehicles is to use organization records by specific vehicle. This includes the miles per gallon (mpg) values listed on the sticker when the vehicle was purchased, or other organization fleet records. If sticker fuel economy values are not available, the recommended approach is to use fuel economy factors from the website [www.fueleconomy.gov](http://www.fueleconomy.gov). This website, operated by the U.S. Department of Energy and the U.S.

Environmental Protection Agency, lists city, highway, and combined fuel economies by make, model, model year, and specific engine type. Current year and historic model year data are both available.

Organizations should consider the following notes on the use of the fueleconomy.gov website to determine fuel economy values and fuel use:

- The default recommended approach is to use the combined city and highway mpg value for organization specific vehicle or closest representative vehicle type.
- The fuel economy values listed for older vehicles were calculated when the vehicle was new. The fuel economy could decline over time, but the decline is not considered to be significant given other uncertainties around use of the data.
- The website also lists estimated GHG emissions, but these are projected emissions based on an average vehicle miles traveled per year. These are not likely to be accurate estimates for fleet vehicles, and are not recommended for use in GHG inventories.

For heavy-duty, on-road vehicles, and non-road vehicles, activity data could come in different forms. For some types of vehicles, activity data could be represented in terms of hours or horsepower-hours of operation, or, for some, it could be by ton-miles shipped. This activity data should be available from organization records. Specific information on fuel consumed per unit of activity data may be available from vehicle suppliers, manufacturers, or in organization records.

For freight transport, organizations should be particularly aware of any long duration idling. Idling can generate significant carbon emissions, and anti-idling strategies can be a cost-effective strategy to reduce emissions. If fuel use is tracked directly, the fuel related to idling is accounted for in the calculation. If fuel use is estimated based on distance data, organizations should be aware of and document the time spent (i.e., hours) idling and make sure it is included in their calculations of GHG emissions.

## 4.2. Fuel Carbon Content and Heat Content

Emissions of CO<sub>2</sub> from fuel combustion are dependent on the amount of carbon in the fuel, which is specific to the fuel type and grade of the fuel. It is recommended that organizations determine the actual carbon content of the fuels consumed, if possible. The most accurate method to determine a fuel's carbon content data is through chemical analysis of the fuel. This data may be obtained directly from the fuel supplier.

Carbon content can also be determined by fuel sampling and analysis. Fuel sampling and analysis should be performed periodically with the frequency dependent on the type of fuel. The sampling and analysis methodologies used should be detailed in the organization's IMP. Refer to 40 CFR Part 75, Appendix G or 40 CFR Part 98, Subpart C for recommended sampling rates and methods.

If actual fuel carbon content is available, either from the supplier or from sampling and analysis, Equation 3 in Section 2 may be used to calculate CO<sub>2</sub> emissions. It is also good practice to track the carbon content values used and to indicate if they vary over time.

If carbon content is not available, it is recommended that organizations determine the actual heat content of the fuel, if possible. The heat content of purchased fuel is often known and provided by the fuel supplier because it is directly related to the useful output or value of the fuel. Heat content can also be determined by fuel sampling and analysis, using methods discussed above. It is recommended that organizations use heat contents determined by one of these methods rather than default heat content, as these should better represent the characteristics of the specific fuel consumed. If actual fuel heat content is available, either from the supplier or from sampling and analysis, then Equation 2 in Section 2 may be used to calculate CO<sub>2</sub> emissions. It is also good practice to track the heat content values used and to indicate if they vary over time.

When determining fuel heat content or tracking fuel use data in energy units, it is important to distinguish between lower heating values (LHV) and higher heating values (HHV), also called net calorific value and gross calorific value, respectively. Heating values describe the amount of energy released when a fuel is burned completely, and LHV and HHV are different methods to measure the amount of energy released. A given fuel, therefore, always has both a LHV and a HHV. The LHV assumes that the steam released during combustion remains as a gas. The HHV assumes that the steam is condensed to a liquid, thus releasing more energy. HHV is typically used in the U.S. and in Canada, while other countries typically use LHV.

All emission factors and default heat content values in this guidance are based on HHV. Therefore, if fuel consumption is measured in LHV units, it must be converted to HHV before calculating emissions. To convert from LHV to HHV, a simplified convention used by the International Energy Agency can be used. For coal and petroleum, divide energy in LHV by 0.95. For natural gas, divide by 0.90.

### 4.3. Emission Factors

If actual fuel carbon content is not available, calculating CO<sub>2</sub> emissions relies on default emission factors. These factors approximate the carbon content of fuel to quantify the amount of CO<sub>2</sub> that will be released when the fuel is combusted. Appendix A provides two main types of default emission factors: factors defined per unit of fuel mass or volume (Table A-1 and A-2), and factors defined by per unit of fuel energy content (Table A-3 and A-4). As discussed in Section 2, using the emission factors per energy unit, along with Equation 2, is preferable to using emission factors per mass or volume. CH<sub>4</sub> and N<sub>2</sub>O emissions depend not only on the fuel characteristics but also on the combustion technology type and control technologies. N<sub>2</sub>O is influenced by catalytic converter design, while CH<sub>4</sub> is a byproduct of combustion, but can also be affected by catalytic converter design. CH<sub>4</sub> and N<sub>2</sub>O emissions are often calculated as a function of vehicle miles traveled. Table B-1 in Appendix B provides emission factors by vehicle type and control technology. Information on the control technology type of each vehicle is posted on an under-the-hood label. To calculate emissions, organizations can multiply the appropriate emission factor by the distance traveled for each vehicle type.

Determining the specific control technologies of vehicles in your fleet gives the most accurate calculation of CH<sub>4</sub> and N<sub>2</sub>O emissions. Organizations should be aware that in order to account for reductions obtained from certain emission savings strategies, it is necessary to use this approach and determine the particular emission control technologies for the vehicles in question.

If determining the specific technologies of the vehicle in a fleet is not possible, or is too labor intensive for a particular fleet, organizations can calculate CH<sub>4</sub> and N<sub>2</sub>O emissions using emission factors by vehicle type and model year, provided in Table B-2. These emission factors are based on a weighted average of available control technologies for each model year.

Emission factors for alternative fuel on-road vehicles and for non-road vehicles are given in Tables B-7 and B-8 of Appendix B.

## Section 5: Completeness

In order for an organization's GHG inventory to be complete, it must include all emission sources within the organization's chosen inventory boundaries. See Chapter 3 of the GHG Protocol for detailed guidance on setting organizational boundaries and Chapter 4 of the GHG Protocol for detailed guidance on setting operational boundaries of the inventory.

On an organizational level, the inventory should include emissions from all applicable facilities and fleets of vehicles. Completeness of organization-wide emissions can be checked by comparing the list of sources included in the GHG emissions inventory with those included in other emissions inventories/environmental reporting, financial reporting, etc.

At the operational level, an organization should include all GHG emissions from the sources included in their inventory. Possible GHG emission sources are stationary fuel combustion, combustion of fuels from mobile sources, purchases of electricity, emissions from air conditioning equipment, and process or fugitive emissions. Organizations may refer to this guidance document for calculating emissions from mobile source fuel combustion, and to The Center's GHG Guidance documents for calculating emissions from other sources. For example, the calculation of HFC and PFC emissions from mobile source air conditioning equipment is described in the Center's guidance "Direct Fugitive Emissions from Refrigeration, Air Conditioning, Fire Suppression, and Industrial Gases."

As described in Chapter 1 of the GHG Protocol, there is no materiality threshold set for reporting emissions. The materiality of a source can only be established after it has been assessed. This does not necessarily require a rigorous quantification of all sources, but at a minimum, an estimate based on available data should be developed for all sources.

## Section 6: Uncertainty Assessment

There is uncertainty associated with all methods of calculating emissions from mobile combustion sources. EPA does not recommend that organizations quantify uncertainty as +/- percentage of emissions or in terms of data quality indicators.

It is recommended that organizations attempt to identify the areas of uncertainty in their emissions and make an effort to use the most accurate data possible. The accuracy of calculating emissions from fuel combustion in mobile sources is partially determined by the availability of data on the amount of fuel consumed or purchased. If the amount of fuel combusted is directly measured or metered, then the resulting uncertainty should be fairly low. Data on the quantity of fuel purchased should also be a fairly accurate representation of fuel combusted, given that any necessary adjustments are made for changes in fuel inventory, fuel used as feedstock, etc. However, uncertainty may arise if only dollar value of fuels purchased is used to estimate fuel consumption. If fuel economy factors are used to estimate fuel use, uncertainty may arise if distance traveled and/or fuel economy is roughly estimated.

The accuracy of calculating emissions from mobile combustion sources is also determined by the factors used to convert fuel use into emissions. Uncertainty in the factors is primarily due to the variability in which they are measured, and the variability of the supply source.

## Section 7: Documentation

Organizations should report data for the appropriate types of mobile sources listed in Table 2. In order to ensure that emissions calculations are transparent and verifiable, the documentation sources listed should be maintained. These documentation sources should be collected to ensure the accuracy and transparency of the data, and should also be included in the organization's IMP.

---

**Table 2: Documentation Sources for Mobile Combustion**

---

<b>Data</b>	<b>Documentation Source</b>
Fuel consumption data	Purchase receipts or utility bills; delivery receipts; contract purchase or firm purchase records; stock inventory documentation; metered fuel documentation
Distance traveled data	Official odometer logs or other records of vehicle distance traveled
Fuel economy data	Company fleet records, showing data on fuel economy; vehicle manufacturer documentation showing fuel economy
Heat contents and carbon contents used other than defaults provided	Purchase receipts or utility bills; delivery receipts; contract purchase or firm purchase records; other documentation from suppliers; EIA, EPA or industry reports
Prices used to convert dollars of purchased to amount or energy content of fuel consumed	Purchase receipts; delivery receipts; contract purchase or fuel firm purchase records; EIA, EPA or industry reports
All assumptions made in calculating fuel consumption, heat contents, and emission factors	All applicable sources

---



## Section 8: Inventory Quality Assurance and Quality Control (QA/QC)

Chapter 7 of the GHG Protocol provides general guidelines for implementing a QA/QC process for all emissions calculations. For mobile combustion sources, activity data and emission factors can be verified using a variety of approaches:

- Fuel energy use data can be compared with data provided to Department of Energy or other EPA reports or surveys.
- If any emission factors were calculated or obtained from the fuel supplier, these factors can be compared to U.S. average emission factors.
- If actual data are available for both fuel use and distance traveled, distance can be divided by fuel use to calculate fuel economy. This can be compared to expected fuel economy for that vehicle type as a way to check the accuracy of the actual data.

## Appendix A: Default CO<sub>2</sub> Emission Factors

This appendix contains default factors for use in calculating CO<sub>2</sub> emissions for different types of transportation fuels, using the method described in Section 2.

The emission factors in Table A-1 and A-2 can be used in Equation 1 from Section 2 to calculate GHG emissions if fuel use is known only in mass or volume units, and no information is available about the fuel heat content or carbon content. These emission factors are developed by multiplying the emission factors in Table A-3 and A-4 by the default heat content of the fuels, which is also shown in Table A-1 and A-2.

The emission factors in Table A-3 and A-4 can be used in Equation 2 from Section 2 to calculate GHG emissions when the actual fuel heat content is known or when the fuel use is provided in energy units.

All CO<sub>2</sub> emission factors assume that 100 percent of the carbon content of the fuel is oxidized to CO<sub>2</sub>, as is recommended by the Intergovernmental Panel on Climate Change (IPCC).

**Table A-1: Emission Factors for Equation 1 (EF<sub>1</sub>) - Emissions per Mass or Volume Unit for Fossil Fuel Combustion**

<b>Fuel</b>	<b>Heat Content (HHV)</b>	<b>Emission Factor</b>
<b>Liquid Fuels</b>	(mmBtu/gal)	(kg CO <sub>2</sub> /gal)
Aviation Gasoline	0.120	8.31
Diesel Fuel	0.138	10.21
Kerosene-type Jet Fuel	0.135	9.75
Liquefied Natural Gas (LNG)	0.084	4.46
Liquefied Petroleum Gases (LPG)	0.092	5.68
Motor Gasoline	0.125	8.78
Residual Fuel Oil	0.150	11.27
<b>Gaseous Fuels</b>	(mmBtu/scf)	(kg CO <sub>2</sub> /scf)
Compressed Natural gas	0.001026	0.05444

**Table A-2: Emission Factors for Equation 1 (EF<sub>1</sub>) - Emissions per Mass or Volume Unit for Biomass Fuel Combustion**

<b>Fuel</b>	<b>Heat Content (HHV)</b>	<b>Emission Factors</b>
<b>Liquid Fuels</b>	(mmBtu/gal)	(kg CO <sub>2</sub> /gal)
Biodiesel (100%)	0.128	9.45
Ethanol (100%)	0.084	5.75

**Table A-3: Emission Factors for Equation 2 (EF<sub>2</sub>) - Emissions per Energy Unit for Fossil Fuel Combustion**

<b>Fuel</b>	<b>Emission Factors</b>
<b>Liquid Fuels</b>	(kg CO <sub>2</sub> /mmBtu)
Aviation Gasoline	69.25
Diesel Fuel	73.96
Kerosene-type Jet Fuel	72.22
Liquefied Natural Gas (LNG)	53.06
Liquefied Petroleum Gases (LPG)	61.71
Motor Gasoline	70.22
Residual Fuel Oil	75.10
<b>Gaseous Fuels</b>	
Compressed Natural Gas	53.06

**Table A-4: Emission Factors for Equation 2 (EF<sub>2</sub>) - Emissions per Energy Unit for Biomass Fuel Combustion**

<b>Fuel</b>	<b>Emission Factors</b>
<b>Liquid Fuels</b>	(kg CO <sub>2</sub> /mmBtu)
Biodiesel (100%)	73.84
Ethanol (100%)	68.44

Source for the emission factors in this appendix: Federal Register (2013) EPA; 40 CFR Part 98; 2013 Revisions to the Greenhouse Gas Reporting Rule and Final Confidentiality Determinations for New or Substantially Revised Data Elements; Final Rule. November 29, 2013. Table C-1, Table C-2, Table AA-1. <http://www.gpo.gov/fdsys/pkg/FR-2013-11-29/pdf/2013-27996.pdf>.

LNG sourced from: GREET™ Software, GREET1\_2013 Model, Argonne National Laboratory. The GREET model provides carbon content and fuel density, which are used to develop the CO<sub>2</sub> emission factor.

<sup>3</sup>U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013, EPA 430-R-15-003, April 2015.

## Appendix B: Default CH<sub>4</sub> and N<sub>2</sub>O Emission Factors

The U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks ("EPA Inventory") provides a summary of tests that have been performed to determine CH<sub>4</sub> and N<sub>2</sub>O emissions from mobile sources.<sup>3</sup> Annex 3, Table A-105 of the EPA Inventory lists CH<sub>4</sub> and N<sub>2</sub>O emission factors by different types of onroad vehicles and control technologies (see Table B-1). Also listed is the percent of the different control technologies installed by model year of vehicle (see Tables B-3 through B-6). These two sources can be combined to determine CH<sub>4</sub> and N<sub>2</sub>O emission factors by model year of vehicle as shown in Table B-2. The methodologies and sources used to derive the factors in these tables are documented in the EPA Inventory.

**Table B-1: CH<sub>4</sub> and N<sub>2</sub>O Emission Factors for On-Road Vehicles**

Vehicle Type/Control Technology	Emission Factor	
	(g CH <sub>4</sub> /mile)	(g N <sub>2</sub> O/mile)
<b>Gasoline Passenger Cars</b>		
EPA Tier 2	0.0173	0.0036
Low Emission Vehicles	0.0105	0.0150
EPA Tier 1	0.0271	0.0429
EPA Tier 0	0.0704	0.0647
Oxidation Catalyst	0.1355	0.0504
Non-Catalyst	0.1696	0.0197
Uncontrolled	0.1780	0.0197
<b>Gasoline Light-Duty Trucks</b>		
EPA Tier 2	0.0163	0.0066
Low Emission Vehicles	0.0148	0.0157
EPA Tier 1	0.0452	0.0871
EPA Tier 0	0.0776	0.1056
Oxidation Catalyst	0.1516	0.0639
Non-Catalyst	0.1908	0.0218
Uncontrolled	0.2024	0.0220
<b>Gasoline Heavy-Duty Vehicles</b>		
EPA Tier 2	0.0333	0.0134
Low Emission Vehicles	0.0303	0.0320
EPA Tier 1	0.0655	0.1750
EPA Tier 0	0.2630	0.2135
Oxidation Catalyst	0.2356	0.1317
Non-Catalyst	0.4181	0.0473
Uncontrolled	0.4604	0.0497
<b>Diesel Passenger Cars</b>		
Advanced	0.0005	0.0010
Moderate	0.0005	0.0010
Uncontrolled	0.0006	0.0012
<b>Diesel Light Trucks</b>		
Advanced	0.0010	0.0015
Moderate	0.0009	0.0014
Uncontrolled	0.0011	0.0017

Vehicle Type/Control Technology	Emission Factor	
	(g CH <sub>4</sub> /mile)	(g N <sub>2</sub> O/mile)
<b>Diesel Medium-and Heavy-Duty Trucks and Buses</b>		
Aftertreatment	0.0051	0.0048
Advanced	0.0051	0.0048
Moderate	0.0051	0.0048
Uncontrolled	0.0051	0.0048
<b>Motorcycles</b>		
Non-catalyst Control	0.0672	0.0069
Uncontrolled	0.0899	0.0087

Table B-2: Weighted Average Model Year CH<sub>4</sub> and N<sub>2</sub>O Emission Factors for On-Road Vehicles

Vehicle Type/Model Year	Emission Factor		Vehicle Type/Model Year	Emission Factor	
	(g CH <sub>4</sub> /mile)	(g N <sub>2</sub> O/mile)		(g CH <sub>4</sub> /mile)	(g N <sub>2</sub> O/mile)
<b>Gasoline Fueled Vehicles Passenger Cars</b>			<b>Gasoline Fueled Vehicles Vans, Pickup Trucks, &amp; SUVs</b>		
1973-74	0.1696	0.0197	1973-74	0.1908	0.0218
1975	0.1423	0.0443	1975	0.1634	0.0513
1976-77	0.1406	0.0458	1976	0.1594	0.0555
1978-79	0.1389	0.0473	1977-78	0.1614	0.0534
1980	0.1326	0.0499	1979-80	0.1594	0.0555
1981	0.0802	0.0626	1981	0.1479	0.0660
1982	0.0795	0.0627	1982	0.1442	0.0681
1983	0.0782	0.0630	1983	0.1368	0.0722
1984-93	0.0704	0.0647	1984	0.1294	0.0764
1994	0.0531	0.0560	1985	0.1220	0.0806
1995	0.0358	0.0473	1986	0.1146	0.0848
1996	0.0272	0.0426	1987-93	0.0813	0.1035
1997	0.0268	0.0422	1994	0.0646	0.0982
1998	0.0249	0.0393	1995	0.0517	0.0908
1999	0.0216	0.0337	1996	0.0452	0.0871
2000	0.0178	0.0273	1997	0.0452	0.0871
2001	0.0110	0.0158	1998	0.0391	0.0728
2002	0.0107	0.0153	1999	0.0321	0.0564
2003	0.0114	0.0135	2000	0.0346	0.0621
2004	0.0145	0.0083	2001	0.0151	0.0164
2005	0.0147	0.0079	2002	0.0178	0.0228
2006	0.0161	0.0057	2003	0.0155	0.0114
2007	0.0170	0.0041	2004	0.0152	0.0132
2008	0.0172	0.0038	2005	0.0157	0.0101
2009-present	0.0173	0.0036	2006	0.0159	0.0089
			2007	0.0161	0.0079
			2008-present	0.0163	0.0066

Vehicle Type/Model Year	Emission Factor		Vehicle Type/Model Year	Emission Factor	
	(g CH <sub>4</sub> /mile)	(g N <sub>2</sub> O/mile)		(g CH <sub>4</sub> /mile)	(g N <sub>2</sub> O/mile)
<b>Gasoline Fueled Vehicles</b>			<b>Gasoline Fueled Vehicles</b>		
<b>Heavy-Duty Vehicles</b>			<b>Motorcycles</b>		
<1981	0.4604	0.0497	1960-1995	0.0899	0.0087
1982-84	0.4492	0.0538	1996-present	0.0672	0.0069
1985-86	0.4090	0.0515			
1987	0.3675	0.0849			
1988-89	0.3492	0.0933			
1990-95	0.3246	0.1142	<b>Diesel Fueled Vehicles</b>		
1996	0.1278	0.1680	<b>Passenger Cars</b>		
1997	0.0924	0.1726	1960-1982	0.0006	0.0012
1998	0.0641	0.1693	1983-1995	0.0005	0.0010
1999	0.0578	0.1435	1996-present	0.0005	0.0010
2000	0.0493	0.1092			
2001	0.0528	0.1235	<b>Light Trucks</b>		
2002	0.0546	0.1307	1960-1982	0.0011	0.0017
2003	0.0533	0.1240	1983-1995	0.0009	0.0014
2004	0.0341	0.0285	1996-present	0.0010	0.0015
2005	0.0326	0.0177			
2006	0.0327	0.0171	<b>Medium- and Heavy-Duty Vehicles</b>		
2007	0.033	0.0153	1960-present	0.0051	0.0048
2008-present	0.0333	0.0134			

Table B-3: Control Technology Assignments for Gasoline Passenger Cars

Model Years	Non-catalyst	Oxidation	EPA Tier 0	EPA Tier 1	LEV	EPA Tier 2
1973-74	100	–	–	–	–	–
1975	20	80	–	–	–	–
1976-77	15	85	–	–	–	–
1978-79	10	90	–	–	–	–
1980	5	88	7	–	–	–
1981	–	15	85	–	–	–
1982	–	14	86	–	–	–
1983	–	12	88	–	–	–
1984-93	–	–	100	–	–	–
1994	–	–	60	40	–	–
1995	–	–	20	80	–	–
1996	–	–	1	97	2	–
1997	–	–	0.5	96.5	3	–
1998	–	–	<1	87	13	–
1999	–	–	<1	67	33	–

Model Years	Non-catalyst	Oxidation	EPA Tier 0	EPA Tier 1	LEV	EPA Tier 2
2000	–	–	–	44	56	–
2001	–	–	–	3	97	–
2002	–	–	–	1	99	–
2003	–	–	–	<1	87	13
2004	–	–	–	<1	41	59
2005	–	–	–	–	38	62
2006	–	–	–	–	18	82
2007	–	–	–	–	4	96
2008	–	–	–	–	2	98
2009-13	–	–	–	–	–	100

Table B-4: Control Technology Assignments for Gasoline Light-Duty Trucks

Model Years	Non-catalyst	Oxidation	EPA Tier 0	EPA Tier 1	LEV	EPA Tier 2
1973-74	100	–	–	–	–	–
1975	30	70	–	–	–	–
1976	20	80	–	–	–	–
1977-78	25	75	–	–	–	–
1979-80	20	80	–	–	–	–
1981	–	95	5	–	–	–
1982	–	90	10	–	–	–
1983	–	80	20	–	–	–
1984	–	70	30	–	–	–
1985	–	60	40	–	–	–
1986	–	50	50	–	–	–
1987-93	–	5	95	–	–	–
1994	–	–	60	40	–	–
1995	–	–	20	80	–	–
1996	–	–	–	100	–	–
1997	–	–	–	100	–	–
1998	–	–	–	80	20	–
1999	–	–	–	57	43	–
2000	–	–	–	65	35	–
2001	–	–	–	1	99	–
2002	–	–	–	10	90	–
2003	–	–	–	<1	53	47
2004	–	–	–	–	72	28
2005	–	–	–	–	38	62
2006	–	–	–	–	25	75
2007	–	–	–	–	14	86
2008-13	–	–	–	–	–	100

**Table B-5: Control Technology Assignments for Gasoline Heavy-Duty Vehicles**

Model Years	Uncontrolled	Non-catalyst	Oxidation	EPA Tier 0	EPA Tier 1	LEV	EPA Tier 2
≤1981	100	–	–	–	–	–	–
1982-84	95	–	5	–	–	–	–
1985-86	–	95	5	–	–	–	–
1987	–	70	15	15	–	–	–
1988-89	–	60	25	15	–	–	–
1990-95	–	45	30	25	–	–	–
1996	–	–	25	10	65	–	–
1997	–	–	10	5	85	–	–
1998	–	–	–	–	96	4	–
1999	–	–	–	–	78	22	–
2000	–	–	–	–	54	46	–
2001	–	–	–	–	64	36	–
2002	–	–	–	–	69	31	–
2003	–	–	–	–	65	30	5
2004	–	–	–	–	5	37	59
2005	–	–	–	–	–	23	77
2006	–	–	–	–	–	20	80
2007	–	–	–	–	–	10	90
2008-13	–	–	–	–	–	–	100

**Table B-6: Control Technology Assignments for Diesel On-Road Vehicles and Motorcycles**

Vehicle Type/Control Technology	Model Years
<b>Diesel Passenger Cars and Light-Duty Trucks</b>	
Uncontrolled	1960-82
Moderate control	1983-95
Advanced control	1996-2013
<b>Diesel Medium- and Heavy-Duty Trucks and Buses</b>	
Uncontrolled	1960-90
Moderate control	1991-2003
Advanced control	2004-06
Aftertreatment	2007-13
<b>Motorcycles</b>	
Uncontrolled	1960-95
Non-catalyst controls	1996-2013



Table B-7 shows the default CH<sub>4</sub> and N<sub>2</sub>O emission factors for alternative fuel vehicles by vehicle and fuel type.

Vehicle Type/Fuel Type	Emission Factor	
	(g CH <sub>4</sub> /mile)	(g N <sub>2</sub> O/mile)
<b>Light-duty Vehicles</b>		
CNG	0.737	0.050
LPG	0.037	0.067
Ethanol	0.055	0.067
Biodiesel	0.0005	0.001
<b>Medium- and Heavy-Duty Trucks</b>		
CNG	1.966	0.175
LNG	1.966	0.175
LPG	0.066	0.175
Ethanol	0.197	0.175
Biodiesel	0.005	0.005
<b>Buses</b>		
CNG	1.966	0.175
Ethanol	0.197	0.175
Biodiesel	0.005	0.005

Table B-8 shows the default CH<sub>4</sub> and N<sub>2</sub>O emission factors for non-road vehicles by vehicle and fuel type. These emission factors are based on emission factors in Table A-107 of the EPA Inventory, which are given in terms of mass of emissions per mass of fuel combusted. The emission factors are converted to emissions per gallon of fuel using the fuel density conversions in Annex 6.5 of the EPA Inventory. Emission factors for LPG and biodiesel vehicles are assumed to be equal to gasoline and diesel vehicles, respectively.

Vehicle Type/Fuel Type	Emission Factor	
	(g CH <sub>4</sub> /gal fuel)	(g N <sub>2</sub> O/gal fuel)
<b>Ships and Boats</b>		
Residual Fuel Oil	0.11	0.57
Gasoline	0.64	0.22
Diesel	0.06	0.45
<b>Rail</b>		
Diesel	0.80	0.26
<b>Agricultural Equipment</b>		
Gasoline	1.26	0.22
Diesel	1.44	0.26

Vehicle Type/Fuel Type	Emission Factor	
	(g CH <sub>4</sub> /gal fuel)	(g N <sub>2</sub> O/gal fuel)
<b>Construction/Mining Equipment</b>		
Gasoline	0.50	0.22
Diesel	0.57	0.26
<b>Aircraft</b>		
Jet Fuel	0.00	0.30
Aviation Gasoline	7.06	0.11
<b>Other Non-Road</b>		
Gasoline	0.50	0.22
Diesel	0.57	0.26
LPG	0.50	0.22
Biodiesel	0.57	0.26

Source for the emission factors in this appendix: U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013, EPA 430-R-15-003, April 2015, Tables A-101 through A-107