Calculating CO2 Emissions from Mobile Sources

Guidance to calculation worksheets

I. Overview

I.A. Purpose and domain of this section

This guidance is intended to facilitate corporate-level measurement and reporting of greenhouse gases (GHG) emissions from transportation and other mobile sources. The section addresses direct GHG emissions from owned or controlled mobile sources and indirect emissions from the use of transportation sources that are owned or controlled by other entities. In this tool the following categories of mobile sources are covered:

- Road transport
- Rail transport
- Air transport
- Water transport

This is a cross-sectoral guideline which should be applied by all industry and service sectors whose operations involve the combustion of fossil fuel in mobile sources or the purchase of freight and/or travel services.

I.B. Assumptions

This guidance is based on the assumption that all carbon burned as fuels is emitted mostly as carbon dioxide (CO_2), CO, and VOCs (including CH_4) except for the unoxidized fraction which remains as ash or soot. CO and VOCs are eventually oxidized to CO_2 in the atmosphere.

If companies purchase electricity for owned or operated electric vehicles and have records of electricity purchased for that purpose, the related emissions should be reported as indirect emissions under scope 2 in the GHG Protocol, 'Stationary Combustion Tool'.

I.C. Direct Versus Indirect Emissions

Corporate transportation emissions can take the form of either direct or indirect emissions. Direct emissions refer to only those emissions that are associated with owned or controlled sources, such as company owned vehicle fleets and corporate aircraft. Indirect emissions refer to all other company-related emissions, including employee commuting, short-term vehicle rentals, and upstream/downstream transportation emissions, such as those associated with material inputs or consumer use. This tool allows calculation of direct and relevant indirect emissions. Table 1 provides a broad guidance to help users classify their direct and/or indirect emissions.

I.D. Choice of Greenhouse Gases

The degree of difficulty in calculating transportation emissions depends largely on which gases are included in the analysis. In most cases, CO_2 emissions are relatively straightforward to estimate, since they are primarily dependent on only two factors: the type and quantity of fuel burned.[1] N_2O

[1] Some variability does exist in the fraction of gasoline oxidized (one of the determinants of CO_2 emissions from combusting fuel), depending on the transportation equipment used. However this variability is minimal. In the *U.S. Inventory*, this fraction is assumed to be 99 percent. Variations in the energy content and carbon content of different fuel formulations (e.g., summer vs. winter gasoline; reformulated vs. oxygenated vs. conventional) can also introduce some error when applying national GHG emission estimates.

and CH_4 emissions, on the other hand, depend largely on the emissions control equipment used (e.g., type of catalytic converter). Since N_2O and CH_4 emissions comprise a relatively small proportion of overall transportation emissions, only CO_2 emissions estimates are included in this tool. Estimates of N_2O and CH_4 emissions is optional at the discretion of the user. In some cases such as a car rental company, or a company owning a large fleet of vehicles with catalytic controls, emissions from N_2O might be significant. A few sources that provide detailed information on how to calculate N_2O emissions are listed below:
(i) IPCC/UNEP/OECD/IEA (1997) Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Paris: Intergovernmental Panel on Climate Change, United Nations Environment Programme;
(ii) IPCC Good Practice Guidance, 2000;
(iii) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 1999, U.S. Environmental Protection Agency, Office of Atmospheric Programs, EPA , April 2001.

II. Calculation methodology used in the tool

For all mobile sources, one may apply either a fuel-based or distance-based methodology to calculate CO_2 emissions. In the fuel-based approach, fuel consumption is multiplied by the CO_2 emission factor for each fuel type. This emission factor is developed based on the fuel's heat content, the fraction of carbon in the fuel that is oxidized (generally approximately 99% but assumed to be 100% in this tool), and the carbon content coefficient. Since this approach uses previously aggregated fuel consumption data, it is considered "fuel-based." Fuel based approach can be used also when vehicle activity data and fuel economy factors are available that enables calculation of fuel consumption.

In the distance-based method, emissions can be calculated by using distance based emission factors to calculate emissions.

Activity data could be in terms of vehicle kilometers (or miles) traveled, freight ton-kilometers (or miles), passenger-kilometers (or miles), etc. Because the data on fuel are generally more reliable, the fuel-based method is the preferred approach for this tool. The distance based method should only be used as a last resort as it can introduce considerably higher levels of uncertainty in the CO_2 estimates.

III. Choice of Activity Data and Emission Factors

The following section presents possible sources of activity data and lists default emission factors, to be used if customized emission factors are not available.

III. A. Activity Data

Typical data source documentation for the different modes of transport are shown in Table 2. Fuel consumption data will usually be available from fuel receipts or other purchase records.[2] Otherwise, reports may be available on fuel expenditures only (i.e., fuel cost, but not actual fuel quantities). In this case, data on average fuel price are necessary in order to convert expenditures to fuel consumption. This data might be available directly from suppliers. Otherwise, national, regional, or local average fuel price data may be used. Direct measurement data may include information from fuel gauges or storage tanks, available in company records.

[2] When using these receipts, distinguishing actual fuel consumption from fuel stock is important. Any fuel that is purchased but not consumed should not be incorporated into the emissions estimate.

If the distance-based approach is used for road transportation, data on distance traveled by vehicle type are necessary. These data should be available from records of odometer readings or other travel records. Data on fuel economy by vehicle type may be available in company fleet records, including original fleet purchase records. If the distance-based approach is used for air transport, data on distance traveled should be available in company records. Specific information on fuel consumed per unit of distance may be available from aircraft manufacturers or in company records. If the distance-based approach is used for water transport or rail transport, data on distance traveled should be available from company travel records. Data on average fuel consumed per unit of distance should be available in company records, including original purchase records.

- Fuel receipts. These receipts must be broken down by fuel and transportation-use only.
- Direct measurements of fuel use. This data can be obtained from vehicle fuel gauges or storage tanks.
- Otherwise, data can be obtained from financial records on fuel expenditures. These records can be used to generate estimates of fuel consumption using data on average fuel cost.

III.B. Emission Factors

Table 3 shows the CO_2 default emission factors, depending on fuel type. In the case of road transportation, companies and other entities have the option to override these defaults if they have appropriate data on the type of fuel used (i.e., the type and proportion of fuel additives) based on fuel characteristics for geographical regions. To do so, companies should specify the location where fuel is purchased and use default emission factors, for that geographic region. Companies may base customized emission factors on company-specific heat rates and/or carbon content coefficients for each fuel combusted. These data may be available from fuel purchase records.

In most cases, default emission factors will be used, based on generic fuel type categories (e.g., unleaded gasoline, diesel, etc.). However, these emission factors may be customized by using company-specific information on fuel characteristics, based on either a) company-specific heat rate and/or carbon content coefficient information; or b) the location of gasoline purchases

IV. Description of Calculation Methods

This section describes the methods for calculating GHG emissions from transportation sources. Section IV.A. describes the fuel-based method and Section IV.B. describes the distance-based method for road transportation, air transport, water-borne sources (i.e., boat transportation) and rail transport. Both methods are available for all modes, however the fuel-based method is the preferred approach.

IVA. Fuel-based Method: Calculations Based on Aggregated Fuel Consumption Data

This section outlines the necessary steps for calculating CO_2 emissions from mobile sources using the fuel-based method, which is essentially the same as the fuel-based approach used to estimate GHG emissions from stationary combustion sources (see footnote 1). The major difference between stationary and mobile GHG emissions estimates is the different types of fuels and fuel emission factors for the two sources, although some are similar.

The fuel-based approach is fairly straightforward and requires essentially two main steps:

Step 1: Gather fuel consumption data by fuel type. Fuel use data can be obtained from several different sources including fuel receipts, financial records on fuel expenditures, or direct measurements of fuel use. More detail on choice of fuel use data can be found in Section III.A. When the amount of fuel is not known, it can be calculated based on distance traveled and an efficiency factor of fuel-per-distance(such as miles per gallon, or liters per 100km) using Steps 1.1 and 1.2.

Step 1.1: Collect data on distance traveled by vehicle type and fuel type. Distance traveled data can basically come in three forms, distance (e.g., kilometers) passenger-distance (e.g., passenger-kms), or freight distance (e.g., ton-miles).

Step 1.2: Convert distance traveled data into fuel use values based on fuel economy factors. Fuel economy factors depend on the type, age, and operating practice of the vehicle in question. There are also different fuel economy factors for each of the different types of distance traveled activity data. Several default factors are given in Table 4 for different types of mobile sources.

> *Fuel Use = Distance x Fuel Economy Factor*
>
> Note: the units for the fuel economy factor will depend on the type of distance traveled activity data known (e.g., gallons per ton-mile if ton-miles given).

Step 2: Convert fuel estimate to CO_2 emissions by multiplying results from step 1 by fuel-specific factors. There are different methods available to convert fuel use data into CO_2 emissions. The recommended approach is to first convert fuel use data into an energy value using the heating value of the fuel (if fuel use data is not first collected in terms of energy). The next step is to multiply by the emission factor of the fuel. Default or customized factors can be used (see Table 3).

The fuel-based approach is the same for the different modes of transportation; road transport, air transport, water transport and rail transport. Differences arise for different types of fuels used in that the gasoline factors (primarily used for road transport) differ based on geographic area more so than other fuels. The following equation outlines the recommended approach to calculating CO_2 emissions based on fuel use (assuming data is first obtained in terms of mass or volume).

> *CO_2 Emissions = Fuel Used x Heating Value x Emission factor*

IV.B. Distance-based Method: Calculations Based on Distance Traveled and Distance-based Emission Factors

This section outlines the necessary steps for calculating CO_2 emissions from mobile sources using the distance-based method. This method can be used when vehicle activity data is in the form of distance traveled but fuel economy data is not available. In this case distance-based emission factors will be required to calculate CO_2 emissions.

Calculating emissions requires two main steps:

Step 1: Collect data on distance traveled by vehicle type and fuel type. Distance traveled data can basically come in three forms, distance (e.g., kilometers) passenger-distance (e.g., passenger-kms), or freight distance (e.g., ton-miles).

Step 2: Convert distance estimate to CO_2 emissions by multiplying results from step 1 by distance based emission factors. Several distance based default emission factors are given in Table 5 for different types of mobile sources and activity data.

The following equation outlines the approach to calculating emissions based on distance traveled when fuel economy data is not available.

$$CO_2 \text{ Emissions} = \text{Distance Traveled} \times \text{Emission factor}$$

V. Choice of Methods

As discussed in section IV, the fuel-based method is the preferred approach for all modes. There is greater uncertainty associated with calculations that are based on fuel expenditure or travel data. Deciding which approach to take – fuel-based or distance-based – depends on data availability. If neither the fuel-based or distance-based criteria can be met, additional data must be collected. Below are the criteria for determining which approach is feasible:

V.A. Criteria for Fuel-based Method

- Are transportation-specific fuel purchase records available?[3] – OR –
- Are direct measurement data available (e.g., vehicle fuel gauge data)? – OR –
- Are financial records that summarize expenses on fuel available?

V.B. Criteria for Distance-based Method

- Are distance activity data by vehicle type available?
- Are fuel economy factors by vehicle type available?
- Are distance based emission factors available?

VI. Inventory Quality Assurance/Quality Control

To ensure the credibility of the inventory, rigorous QA/QC procedures should be followed to ensure the accuracy, transparency, and verifiability of the estimates. The following issues must be addressed:

- Chapter 8 in the GHG protocol – 1st Edition, provides general guidelines for implementing a QA/QC process for all emission estimates. For transportation sources, this process should include a review of all activity data (e.g., fuel consumption data, distance traveled estimates), as well as any information used to develop customized emission factors (e.g., location of fuel purchases, "cruising" aircraft fuel consumption).

[3] If fuel purchase records are not separated for transportation only, you may use the "stationary combustion tool (available on the GHG Protocol website: www.ghgprotocol.org)."

- Checks should ensure that the best and most accurate emission factors are being used. If custom emission factors are available, are there any significant differences with the default numbers?

VI.A. Uncertainty Assessment

Uncertainties in calculating transportation emissions from mobile sources may result from several factors:

- If fuel-based method is used, fuel receipts are incomplete or do not clearly indicate purchases of specific fuel types;
- If fuel-based method is used, conversion of fuel expenditure data to fuel quantity based on fuel price data;
- If distance-based method is used, estimates of distance traveled and/or fuel economy are roughly estimated; and
- Emission factors are not customized to reflect actual conditions (e.g., default CO_2 emission factors are used for highway sources, instead of customized factors based on location of fuel purchases).

In general, use of the fuel-based methods for produces less uncertainty than use of the distance-based methods.

VII. Reporting and Documentation

While documentation is not required to be reported or provided, it is generally necessary for companies or other entities interested in having their emissions audited and certified. In order to ensure that estimates are independently verifiable, quantitative input data used to develop emission estimates should be clearly documented, including listing of relevant year to which the data applies. Documentation should take the form of hard copies whenever possible, however electronic copies may be provided in certain cases. Table 2 shows the suggested documentation for mobile sources.

Table 1. Direct and Indirect Emissions from Mobile Sources

Direct Emissions (Scope 1 Emissions)	**Indirect Emissions from Import of Energy** (Scope 2 Emissions)[4]	**Other Indirect Emissions** (Scope 3 Emissions)
Travel in any owned or controlled[5] transportation devices, e.g. emissions due to fuel combustion from company owned airplanes, cars, trucks etc	Import of electricity or steam to drive any owned or controlled transportation devices, e.g. import of electricity to drive company owned or controlled electric trains	Travel in any transportation devices owned or controlled by another entity, e.g. employee commuting, business travel, goods transportation etc. in transport devices owned or controlled by another entity

Table 2. Documentation for Mobile Sources

Source	**Methodology**	
	Fuel-based	**Distance-based**
Road transportation	Fuel receipts; *or* Fuel expenditure records; *or* Direct measurement records, including official logs of vehicle fuel gauges or storage tanks.	Odometer logs or other records of vehicle miles of travel (must be given by vehicle type); *and* Company fleet records, showing data on fuel economy by vehicle type; *or* Vehicle manufacturer documentation showing fuel economy by vehicle type.
Air Transport	Fuel receipts; *or* Fuel expenditure records; *or* Direct measurement records, including official logs of vehicle fuel gauges or storage tanks.	Company records of fuel consumed per unit-of-distance traveled; *or* Aircraft manufacturer records of fuel consumed per unit-of-distance traveled.
Water Transport	Fuel receipts; *or* Fuel expenditure records; *or* Direct measurement records, including official logs of vehicle fuel gauges or storage tanks.	Odometer logs or other records of miles (kms) of travel (must be given by vehicle type); *and* Company records of fuel consumed per unit-of-distance traveled;

[4] Use stationary combustion tool to calculate scope 2 emissions.
[5] See chapter 3 (Setting Organizational Boundaries) in GHG Protocol – a corporate accounting and reporting standard, October' 2001.

Rail Transport	Fuel receipts; *or* Fuel expenditure records; *or* Direct measurement records, including official logs of vehicle fuel gauges or storage tanks.	Odometer logs or other records of miles(kms) of travel (must be given by vehicle type); *and* Company records of fuel consumed per unit-of-distance traveled;
All Sources	If emission factors are customized, records of calorific values and/or carbon content of fuels; *or* Receipts or other records indicating location of fuel purchases.	

Table 3: Default Emission factors and heating values for different transportation fuels

Fuel type	Based on Lower Heat Value		(derived) LHV	(derived) LHV		(derived) LHV
	kg CO2 / GJ	GJ / litre	GJ/ US gallon	GJ/Imp Gal	GJ / litre	GJ/tonne
Gasoline / petrol	69.25	0.0344	0.1302	0.1564	0.0344	43.5674
Kerosene	71.45	0.0357	0.1351	0.1623	0.0357	44.0768
Jet Fuel	70.72 (EIA)					44.5900
Aviation gasoline	69.11 (EIA)	0.0343	0.1299	0.1561	0.0343	
Diesel	74.01	0.0371	0.1404	0.1687	0.0371	44.1667
Distillate fuel oil No.1	74.01	0.0371	0.1404	0.1687	0.0371	43.9211
Distillate fuel oil No.2	74.01	0.0371	0.1404	0.1687	0.0371	43.9211
Residual Fuel oil#4	74.01	0.0379	0.1435	0.1723	0.0379	
Residual Fuel oil#5	77.30	0.0397	0.1503	0.1805	0.0397	39.9535
Residual Fuel oil#6	77.30	0.0405	0.1533	0.1841	0.0405	40.7586
LPG	63.20	0.0249	0.0942	0.1132	0.0249	45.9779
Lubricants	73.28	0.0382			0.0382	
Anthracite	98.30	0.0271 GJ/kg			0.0271 GJ / kg	
Bituminous coal	94.53	0.0272 - 0.0309 GJ/kg			0.0272 – 0.0309 GJ / kg	
Butane		0.0258			0.0258	
Propane	62.99 (EIA)	0.0240			0.0240	47.3373
Anthracite	98.30					**23.53 ***
Bituminous coal	94.53					**23.53 ***
Sub-bituminous coal	96.00					**23.53 ***
Wood, wood waste	100.44 (EIA)					
Natural gas	56.06	0.035 GJ / standard cubic meter			0.035 GJ / standard cubic meter	

[Source: Emission factors (kg CO2/GJ) based on lower heating values are from IPCC, 1996, Volume 2, Section 1, if not otherwise noted. Lower heating values (GJ/Litre) are derived from higher heating values provided in Table 3-5. In "Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry", American Petroleum Institute, 2001]

Table 4. Default Fuel economy factors for different types of mobile sources and activity data

Vehicle Characteristics			CO2/km traveled
Vehicle Type	***Liters/100km***	***mpg***	***gram CO2 / km***
New small gas/electric hybrid	4.2	56	100.1
Small gas auto, hghwy	7.3	32	175.1
Small gas auto, city	9.0	26	215.5
Medium gas auto, hghwy	7.8	30	186.8
Medium gas auto, city	10.7	22	254.7
Large gas automobile, hwy	9.4	25	224.1
Large gas automobile, city	13.1	18	311.3
Medium Station wagon, hwy	8.7	27	207.5
Med Station wagon, city	11.8	20	280.1
Mini Van, hwy	9.8	24	233.5
Mini Van, city	13.1	18	311.3
Large Van, hwy	13.1	18	311.3
Large Van, city	16.8	14	400.2
Mid size. Pick-up Trucks, hwy	10.7	22	254.7
Pick-up Trucks, city	13.8	17	329.6
Large Pick-up Trucks, hwy	13.1	18	311.3
Large Pick-up Trucks, city	15.7	15	373.5
LPG automobile	11.2	21	266
Diesel automobile	9.8	24	233
Gasoline light truck	16.8	14	400
Gasoline heavy truck	39.2	6	924
Diesel light truck	15.7	15	374
Diesel heavy truck	33.6	7	870
Light motorcycle	3.9	60	93
Diesel bus	35.1	6.7	1034.611322

[Source: Miles per gallon for typical vehicles based on averages from US - EPA 2001 Guide. Also available at www.epa.gov/autoemissions]

Table 5. Default distance based emission factors for different types of mobile sources

(Tables 5.1 to 5.5 are from Environmental Reporting – Guidelines for Company Reporting on GHG Emissions, DEFRA, UK)

Table 5.1: Passenger Road Transport Conversion Factors: Petrol cars					
Size of car and distance units	**Total units travelled**	**Units**	**x**	**kg CO_2 per unit**	**Total kg CO_2**
Small petrol car Max 1.4 litre engine		miles	x	0.28	
		km	x	0.17	
Medium petrol car From 1.4 – 2.1 litres		miles	x	0.36	
		km	x	0.22	
Large petrol car Above 2.1 litres		miles	x	0.44	
		km	x	0.27	
Average Petrol car		miles	x	0.33	
		km	x	0.20	

Source: COPERT II emission factors and Transport Research Laboratory data, combined with real road testing cycle data

Table 5.2: Passenger Road Transport Conversion Factors: Diesel cars					
Size of car and distance units	**Total units travelled**	**Units**	**x**	**kg CO_2 per unit**	**Total kg CO_2**
Small diesel car 2.0 litre or under		miles	x	0.19	
		km	x	0.12	
Large diesel car Over 2.0 litre		miles	x	0.23	
		km	x	0.14	
Average diesel car		miles	x	0.20	
		km	x	0.12	

Source: COPERT II emission factors and Transport Research Laboratory data, combined with real road testing cycle data

Table 5.3: Rail and Air Passenger Transport Conversion Factors					
Method of travel		**Person/kms travelled (pkm)**	**x**	**kg CO_2 per pkm**	**Total kg CO_2**
Rail			x	0.06	
Air[4]	long haul		**x**	0.11	
	short haul		**x**	0.18	

Source: NETCEN, British Airways, DHL, Railtrack, English, Welsh and Scottish Railways LTD.

Table 5.4: Freight Road Mileage Conversion Factors							
Type of lorry	**Tonne km**	**x**	**Litres fuel per km**	**x**	**Fuel conversion factor**		**Total kg CO_2**
Articulated		x	0.40	x	Petrol	2.31	
				x	Diesel	2.68	
				x	LPG	1.51	
Rigid		x	0.35	x	Petrol	2.31	
				x	Diesel	2.68	
				x	LPG	1.51	

Source: Continuing Survey of Road Goods Transport 1997

Table 5.5: Other Freight Road Mileage Conversion Factors					
Freight transport mode		**Tonne km**	**x**	**Factor**	**Total kg CO_2**
Rail			x	0.03	
Air	long haul		x	0.57	
	short haul				
			x	1.58	
Shipping[5]T	small ro-ro		x	0.06	
	large ro-ro				
	small tanker				
	large tanker				
	small bulk carrier				
	large bulk carrier				
			x	0.02	
			x	0.04	
			x	0.003	
			x	0.014	
			x	0.007	

Source: Lloyds Register Marine Research Programme 1990

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3 revised figure in line with factors used in National Air Emissions Inventory
4 Long haul - Asia, Australasia, the Americas, Middle and Far East Short haul - average 500km
5 Small ro-ro - 1,268 deadweight tonnes, max speed 16.2 knots
Large ro-ro - 4,478 deadweight tonnes, max speed 23.2 knots
Small tanker - 844 deadweight tonnes, max speed 8.2 knots
Large Tanker - 18,371deadweight tonnes, max speed 15 knots
Small Bulk carrier - 1,720 deadweight tonnes, max speed 10.9 knots
Large Bulk carrier - 14,201 deadweight tonnes, max speed 11.2 knots