Transport Canada

USER GUIDE FOR URBAN TRANSPORTATION EMISSIONS CALCULATOR (UTEC)

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IBI GROUP

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1. QUICK GUIDE

The Urban Transportation Emissions Calculator (UTEC) is a user-friendly tool for estimating annual emissions of greenhouse gases (GHGs) and key air pollutants from personal, commercial, and public transit vehicles in an urban context.

UTEC is very easy to use and this Quick Guide will describe the basic steps on how to generate results quickly. The quality of the emission estimates will depend on the quality of the input data and ability to tailor default values to local conditions. For more detailed discussion of the inputs, underlying data, calculations, and assumptions, see the other sections of this User Guide.

Running a scenario involves three main tasks: (1) **Scenario Inputs**, (2) **Vehicle Inputs**, and (3) **Results**. These tasks involve 12 basic steps as described below. Optional steps are indicated.

SCENARIO INPUTS

1. **Enter scenario name (optional):** Meaningful scenario names (e.g., Full Bus Rapid Transit Implementation) will aid in keeping track of multiple scenarios

2. **Select evaluation year**: Affects emission results as it is expected that vehicle fuel efficiencies and other emission factors will improve in the future.

3. **Select province/territory**: Allows the Tool to account for the proportion of automobiles vs. light trucks in each province/territory as well as the differing GHG intensities associated with electricity production in each province/territory.

4. **Continue to Vehicle Inputs screen**: Click on the button “Submit and continue to Personal Vehicles”.

VEHICLE INPUTS

Vehicle inputs consist of three screens: Personal Vehicles, Commercial Vehicles, and Public Transit. Each screen follows approximately the same structure.

5. **Enter kilometres travelled**: The primary input to the Tool is vehicle kilometres travelled (VKT) for road vehicles and passenger kilometres travelled (PKT) for rail transit vehicles.

6. **Specify the time period over which kilometres travelled was measured**: VKT or PKT can be entered as tallies for the peak weekday hour, average weekday daily, or annual time period.

7. **Modify expansion factors (optional)**: Expansion factors are used to convert inputted travel data into an annual value. Users are encouraged to tailor expansion factors to local conditions. Default values are generally based on results from large urban areas.

8. **Enter driving conditions (optional)**: The proportion of stop-and-go City driving versus free flow Highway driving is used to estimate fuel efficiency. Default values are generally based on results from large urban areas.

9. **Specify fleet breakdown (optional)**: Different vehicle technologies run on different fuels and have different fuel efficiencies. For each vehicle type, enter the proportion of the vehicle fleet by vehicle-technology. Defaults values are based on national fleet characteristics.

10. **Go to Results or continue to the next Vehicle Inputs screen**: Click on the appropriate button to either proceed to Results or the next Vehicle Inputs screen.

RESULTS

Results are displayed in three tables: Annual Greenhouse Gas Emissions, Annual Criteria Air Contaminant Emissions, and Annual Travel. Note that units for each table vary based on the size of the numbers.

11. **Review results**: UTEC does not save scenarios. Copy Results page to Excel to save results and conduct further analysis if desired.

12. **Modify current scenario or start over**: Click on the appropriate button to return to the Scenario Inputs sheet and make modifications, or clear the scenario and start over. Alternatively, use the tab-like buttons at the top of the screen to go to any input sheet and make modifications.

2. TOOL OVERVIEW

2.1 What is UTEC?

The Urban Transportation Emissions Calculator (UTEC) is a user-friendly tool for estimating annual emissions from personal, commercial, and public transit vehicles. UTEC estimates:

- Annual greenhouse gas (GHG) emissions from the operation of vehicles;
- Annual criteria air contaminant (CAC) emissions from the operation of vehicles; and
- Annual upstream GHG emissions from the production, refining and transportation of transportation fuels, as well as from production of electricity used by electric vehicles.

The target audience for this tool includes, those with responsibility for transportation and land-use planning, academics and other transportation experts, urban transportation providers, and private and public vehicle fleet managers.

2.2 How can you use UTEC?

UTEC can be used for urban transportation emissions estimation in a wide variety of contexts involving different vehicle types (i.e., personal, commercial, and public transit vehicles), fuel technologies (e.g., gasoline, diesel, hybrid, ethanol, biodiesel, etc.), and planning horizons (2006-2031). Sample uses include:

- Determining a baseline level of annual GHG and CAC emissions from passenger transportation for an urban area;
- Forecasting annual GHG and CAC emissions from passenger transportation for an urban area for future years (i.e., 2011, 2016, 2021, 2026, 2031);
- Assessing the emissions implications of a particular transit project (e.g., a new rapid transit line);
- Assessing the emissions implications of converting a portion of a commercial or transit fleet to an alternative fuel (e.g., hybrid-diesel or natural gas buses, biodiesel trucks, etc.)

As discussed below, UTEC estimates emissions from transportation activity data (e.g. vehicle kilometres travelled). It cannot predict the emission implications of different land uses or other transportation demand strategies (e.g., ridematching) directly if activity data is not available.

2.3 What vehicle types and fuel technologies are considered?

The Tool estimates GHG and CAC emissions for the following vehicles:

- **Light-duty passenger vehicles (LDPV)** – Automobiles and light trucks for passenger use less than 6,000 lbs. gross vehicle weight rating (GVWR);
- **Light-duty commercial vehicles (LDCV)** –Trucks for commercial use less than 8,000 lbs. GVWR (e.g., pick-up truck);

- **Medium-duty commercial vehicles (MDCV)** - Trucks for commercial use between 8,000 and 33,000 lbs. GVWR (e.g., box truck);

- **Heavy-duty commercial vehicles (HDCV)** - Trucks for commercial use greater than 33,000 lbs. GVWR (e.g., semi-trailer);

- **Public transit buses (BUS)** – Bus used for public transit;

- **Public transit trolley buses (TB)** – Grid-connected public transit bus (e.g., electrically powered from an overhead wire);

- **Light rail (LR)** – Light transit rail powered by electricity or diesel-fuelled, such as an electric streetcar or the Ottawa O-train, respectively;

- **Subway/Metro (SM)** – Electrically powered subway or metro system; and

- **Heavy rail (HR) (diesel)** – Diesel-fuelled commuter rail.

The Tool also considers the impacts of new technologies and alternative fuels for road vehicles. The vehicle-technology combinations considered for road-vehicles are displayed in the table below.

Exhibit 2-1: Vehicle-Technology Combinations Considered

Technology	Vehicle				
	LDPV	LDCV	MDCV	HDCV	BUS
Gasoline (G)	♦	♦	♦	♦	♦
Diesel (D)	♦	♦	♦	♦	♦
Propane (P)	♦	♦	♦	♦	♦
Compressed Natural Gas (CNG)	♦	♦	♦	♦	♦
Liquefied Natural Gas (LNG)			♦	♦	♦
Ethanol (E10)	♦	♦			
Ethanol (E85)	♦	♦			
Methanol (M85)	♦	♦			
Ethanol-Diesel (ED10)			♦	♦	♦
Biodiesel (B100)			♦	♦	♦
Hybrid (HYB)	♦	♦			♦
Plug-in Hybrid (PHEV)[1]	♦	♦			
Electric Vehicle (EV)	♦	♦			
Fuel Cell (FC)	♦	♦			♦

(1) Plug in Hybrid Electric Vehicle assumes PHEV50/50 (i.e. battery can provide energy for 50km of driving and vehicle operates in battery mode 50% of driving).

2.4 What are the key inputs?

The primary input to the Tool is vehicle kilometres travelled (VKT) for road vehicles and passenger kilometres travelled (PKT) for rail vehicles. These numbers can be entered as tallies for the peak weekday hour, average weekday daily, or annual time period. To improve the accuracy of results, it is strongly recommended that the user modify default values for other inputs, such as expansion factors, and fleet composition, to local conditions, but this is not required to run the Tool.

The key inputs are summarized below and described individually in the Inputs Section.

- **Activity data** – As discussed, the primary input to the Tool is VKT for road vehicles and PKT for rail vehicles, which can be entered as tallies for the peak weekday hour, average weekday daily, or annual time period.

- **Evaluation year** – The user can select from an evaluation year between 2006 and 2031 in five-year increments, corresponding to Census years. Fuel efficiency and emission factors are expected to improve in future years as discussed in the Emission Factors section.

- **Province/territory** – The study province or territory sets the default light duty vehicle fleet composition and the GHG emission factor for electricity generation.

- **Expansion factors** – Expansion factors convert inputted activity data to annual values and have a large influence on final results. Default values are provided based on data from a large urban region, however, tailoring these values to local conditions is recommended, if data is available. Unique expansion factors are provided for personal vehicles, commercial vehicles, and public transit reflecting different travel patterns among these vehicle types.

- **Driving conditions** – For road vehicles, users can modify default values for the proportion of driving in City (i.e., stop and go driving with low average speed) and Highway (i.e., free flow driving with high average speed) conditions. UTEC modifies fuel efficiency based on driving conditions.

- **Fleet composition** – Default fleet composition by road vehicle type and fuel is based on national averages. Users can change this breakdown and specify the proportion of vehicles using alternative fuel technologies.

2.5 What are the main sources of data?

While the data used in UTEC are collected from a variety of sources, the underlying fleet composition, fuel efficiency, and GHG and CAC emission factors were drawn from three primary sources:

- **Canada's Greenhouse Gas Emissions Inventory, Environment Canada** – Updated vehicle operation GHG emission factors for conventional vehicles (i.e. gasoline and diesel powered) were provided by Environment Canada in advance of the release of the 1990-2006 Greenhouse Gas Emissions Inventory (see http://www.ec.gc.ca/pdb/ghg/inventory_report/ 2005_report/tdm-toc_eng.cfm for the *National Inventory Report, 1990-2005: Greenhouse Gas Sources and Sinks in Canada*)

- **MOBILE6.2C outputs from the National Inventory of CAC Emissions, Environment Canada** – Environment Canada prepared runs of MOBILE6.2C[1] for the years 1980 to

[1] MOBILE is a model developed by the U.S. Environmental Protection Agency for estimating pollution from highway vehicles. MOBILE calculates gram per mile emissions of hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), carbon dioxide (CO2), particulate matter (PM) and air toxics from Gas, diesel, and natural-gas-fuelled cars, trucks, buses, and motorcycles for the calendar years between 1952 and 2050. MOBILE is the most recognized model for estimating CAC

2030 using their own projections of technology and fleet changes at the national level. The results from these runs provided CAC emission factors and fuel efficiencies for conventional road vehicles used in UTEC.

- **GHGenius, Natural Resources Canada** - GHGenius is an Excel-based tool developed for Natural Resources Canada, capable of estimating lifecycle emissions of the primary greenhouse gases and criteria pollutants from combustion sources. GHGenius summarizes some of the best data available on emissions factors associated with conventional and alternative fuels. Upstream fuel cycle GHG emission factors for all fuels were derived from GHGenius based on average national values. In addition, fuel efficiencies and vehicle operation GHG and CAC emission factors for alternative fuel vehicles were derived from GHGenius (see http://www.ghgenius.ca/ to access the Tool and all supporting documentation).

2.6 How do I tailor UTEC to my local conditions?

Other than ensuring you have good estimates of travel activity by vehicle class, there are a number of ways that UTEC can be tailored to local conditions.

- **Modify expansion factors** - Expansion factors are used to convert inputted travel data into an annual value. Tailoring expansion factors to local conditions will have a *very significan*t impact on the accuracy of results. The default expansion factors take into account travel characteristics for a large urban area (i.e., metropolitan Toronto area). Travel patterns in the area of interest may be significantly different, so that care should be taken in determining appropriate factors (e.g., if the vast majority of transit travel occurs during the peak periods, then the peak-daily expansion factor will be lower than default values in the Tool).

- **Modify driving conditions** – The level of congestion and amount of highway travel in the area of interest will influence the proportion of stop and go City driving versus free flow highway driving. This has a significant influence on fuel efficiency (it was assumed that City driving consumes 30% more fuel per kilometre than Highway driving).

- **Modify proportion of automobiles and light trucks in light-duty passenger fleet** - The light-duty passenger vehicle type includes many vehicle classes, such as small automobiles, large automobiles, sport utility vehicles, minivans, pick-up trucks, etc. To allow greater accuracy in calculation of fuel consumption and emissions, the light-duty passenger vehicle type is subdivided into automobiles and light trucks. The default proportion of LDPVs in automobile and light trucks is province-specific, but can be further refined to local conditions.

- **Modify breakdown of vehicle fleet by fuel technology** – For each vehicle type, the user can specify the proportion of the fleet by fuel technology (e.g., gasoline, diesel, hybrid, propane, etc.). Default values represent national fleet characteristics.

Certain aspects of UTEC cannot be modified, which puts limits on how far the Tool can be tailored to local conditions. For example, emission factors and fuel efficiencies by vehicle type cannot be modified and are based on national level fleet data, primarily due to data limitations. This may result in underestimates of fuel consumption and emissions in provinces that do not have emission standards for vehicles in operation (e.g. Drive Clean in Ontario) or in provinces with older vehicle

emission from road sources. MOBILE includes over 25 vehicle classifications. The most recent version is MOBILE6.2, which has been adapted by Environment Canada to Canadian conditions as MOBILE6.2C.

fleets (e.g., British Columbia, since many areas do not use road salt). In addition, upstream fuel cycle GHG emission factors for all fuels were derived from GHGenius based on average national values.

Overall, it is expected that UTEC provides good estimates of annual emissions for an urban area provided that the user can reasonably tailor the aforementioned inputs to local conditions. Emission estimates will be less accurate, however, if the fleet under consideration is significantly different from the national average (e.g., a truck fleet with all vehicles purchased in one year) or if it has a less representative speed profile (e.g., only modelling low-speed local traffic). This is particularly the case for CAC emission estimates, which are very sensitive to driving conditions.

2.7 How has UTEC been upgraded?

The first version of UTEC was made available in mid-2006. Given the continually growing body of knowledge with regards to emission estimation, comments received to date, and the desire to enhance the value of the Tool to the target audience, UTEC has been upgraded. Key upgrades include:

- **Updated GHG and CAC emission factors** – Vehicle operation GHG emission factors have been updated to reflect the most recent work from Environment Canada. CAC emission factors for alternative fuel technologies have been updated based on the most current data summarized in GHGenius. Upstream fuel cycle GHG emission factors have been updated based on the most current data summarized in GHGenius. Diesel rail CAC emission factors have been updated based on most recent work from the Locomotive Emissions Monitoring Program by the Railway Association of Canada.

- **Updated fuel efficiencies** –The previous version of UTEC predicted limited improvements in fuel efficiencies over the next 25 years based on MOBILE6.2C forecasts from Environment Canada. Fuel efficiencies have been modified to reflect an annual improvement rate of 0.5%, in line with projections in *Canada's Emission Outlook*, produced by Natural Resources Canada (http://www.nrcan.gc.ca/es/ceo/update.htm).

- **New user interface** – The input screen has been simplified and divided into four screens: Scenario Inputs, Personal Vehicles, Commercial Vehicles, Public Transit. Users can now enter activity data in terms of peak hour, daily, or annual time periods. In addition, to provide user guidance, short descriptions pop up when a user "mouses over" certain inputs.

- **Additional vehicle types and fuel technologies** – To provide greater options to users, two vehicle types have been added: Medium-Duty Commercial Vehicle and Subway/Metro. In addition, three fuel technologies have been added: E-diesel (ED10), biodiesel (BD100), and plug-in hybrid electric vehicle (PHEV).

- **Modified treatment of driving speed/driving conditions** – Users no longer need to enter the average speed and the proportion of driving by road facility type. The input for driving conditions has been simplified to the proportion of driving under city and highway conditions. This change was made to allow greater compatibility with GHGenius, and to allow more efficient estimation of fuel efficiency of alternative fuel vehicles. It also makes it easier for users to tailor driving characteristics to local conditions.

3. INPUTS

3.1 Scenario Inputs

ENTER SCENARIO NAME

The scenario can be anything of your choosing. Choosing meaningful scenario names (e.g., Full Bus Rapid Transit Implementation) will aid in keeping track of multiple scenarios. Note that UTEC cannot save results from multiple scenarios.

SELECT EVALUATION YEAR

The evaluation year will affect emission results as it is expected that vehicle fuel efficiencies and other emission factors will improve in the future. The nature of these changes is discussed later in the sections on Fuel Efficiency, GHG Emission Factors, and CAC Emission Factors. The evaluation years were set in five-year increments from 2006 through 2031 to correspond with Census years as these are the years to which many municipalities have calibrated their travel demand forecasting models.

SELECT PROVINCE/TERRITORY

Selecting the province or territory of the municipality of interest allows the Tool to account for the varied provincial breakdowns of light-duty passenger vehicles (i.e., proportion of automobiles vs. light trucks) as well as the differing GHG intensities associated with electricity production in each province.

3.2 Personal Vehicles

The Personal Vehicles input screen accepts activity and fleet inputs for Light-Duty Passenger Vehicles. This includes cars and light trucks less than 6,000 lbs. GVWR.

ENTER VEHICLE KILOMETRES TRAVELLED BY LDPVS

Vehicle kilometres travelled represents the primary input to the Tool and care should be taken to enter accurate values.

Based on the data available, the user can enter VKT for the peak hour, average weekday, or annual time period. Travel demand models, available in most larger municipalities, generate travel estimates for the peak hour. If modelled VKT data are not available, other methods may be used. For example, if peak hour traffic counts are available, multiplying the peak hour traffic count by the appropriate road length will yield peak hour VKT.

MODIFY PERSONAL VEHICLE EXPANSION FACTORS

Expansion factors are used to convert inputted travel data into an annual value. If the user specified that input VKT is daily or annual, the appropriate expansion factors will automatically set to one.

While all municipalities have unique relationships between peak hour and annual travel, default values take into account travel characteristics for the Toronto area, a large urban region, based on data from the 2001 Transportation Tomorrow Survey. Users are encourage to tailor expansion factors to local conditions.

ENTER PERCENTAGE OF KILOMETRES IN CITY AND HIGHWAY DRIVING

Based on fuel efficiency ratings for new vehicles, stop and go city driving consumes approximately 20% to 65% more fuel per kilometre than free flow highway driving (Fuel Consumption Guide 2008, Office of Energy Efficiency, Natural Resources Canada, 2007). The proportion of City versus Highway driving is used to estimate fuel efficiency for light-duty passenger vehicles. Default values reflect that the majority of driving for personal vehicle is expected to be in stop and go, city conditions.

ENTER BREAKDOWN OF LDPV FLEET

The light-duty passenger vehicle type includes many vehicle classes, such as small automobiles, large automobiles, sport utility vehicles, minivans, pick-up trucks, etc. To allow greater accuracy in calculation of fuel consumption and emissions, the light-duty passenger vehicle type is subdivided into automobiles (LDPV-A) and light trucks (LDPV-T). LDPV-T includes all larger personal vehicles, such as sport utility vehicles, minivans, and pick-up trucks. The default automobile and light truck proportions are province-specific and were determined from 2005 data reported by the Office of Energy Efficiency Comprehensive Energy Use Database, Transportation Sector (http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/index.cfm?fuseaction=Selector.showTree).

ENTER PASSENGER FLEET BREAKDOWN BY FUEL TECHNOLOGY

The Tool allows for 11 different vehicle-technologies for light-duty passenger vehicles, as shown in Exhibit 2-1, above. Users can select up to six LDPV vehicle technologies per scenario. Each vehicle is assumed to travel the same distance annually so that value entered is equivalent to the proportion of the VKT travelled by each vehicle technology. The sum of percentages must be 100%.

Defaults values for fleet breakdown are based on national VKT data by vehicle type reported in the Environment Canada MOBILE6.2C output. Assumptions regarding alternative fuel technologies are described in the discussion of Emission Factors.

3.3 Commercial Vehicles

The Commercial Vehicles input screen accepts activity and fleet inputs for Light-Duty Commercial Vehicles (trucks less than 8,000 lbs. GVWR), Medium-Duty Commercial Vehicles (trucks between 8,000 and 33,000 lbs. GVWR), and Heavy-Duty Commercial Vehicles (trucks heavier than 33,000 lbs. GVWR).

ENTER VEHICLE KILOMETRES TRAVELLED BY COMMERCIAL VEHICLES

Vehicle kilometres travelled represents the primary input to the Tool and care should be taken to enter accurate values.

Based on the data available, the user can enter VKT for the peak hour, average weekday, or annual time period. Travel demand models, available in most larger municipalities, generate travel estimates for the peak hour, although they may not consider commercial vehicles. If modelled VKT data are not available, other methods may be used, such as cordon counts or assuming that commercial travel represents a certain proportion of passenger travel. Alternatively, fleet managers may keep records or their truck travel on a daily or annual basis.

MODIFY COMMERCIAL VEHICLE EXPANSION FACTORS

Expansion factors are used to convert inputted travel data into an annual value. If the user specified that input VKT is daily or annual, the appropriate expansion factors will automatically set to one.

Users are encouraged to tailor expansion factors to local conditions. The default value for the peak hour to daily expansion factor takes into account travel characteristics for the Toronto area, a large urban region, based on data from the Ministry of Transportation, Ontario (MTO) 2001 Commercial Vehicle Survey and the University of Toronto Data Management Group cordon count database (also 2001 counts). It is an average of expansion factors for each commercial vehicle type. Based on these sources, the peak hour to daily expansion factor increases with increasing truck size (LCDV = 12, MDCV = 14.5, HDCV = 16). This reflects that travel for larger trucks is spread out more evenly over the day. The user can adjust the default peak hour to daily expansion factor if only one or two commercial vehicle types are being considered.

The daily to annual expansion factor is based on typical commercial travel patterns.

ENTER PERCENTAGE OF KILOMETRES IN CITY AND HIGHWAY DRIVING

The proportion of City versus Highway driving is used to estimate fuel efficiency for commercial vehicles. Default values reflect that, with increasing vehicle size, average trip distance increases and a greater proportion of driving tends to occur in free flow, highway conditions.

ENTER COMMERCIAL FLEET BREAKDOWN BY FUEL TECHNOLOGY

The Tool allows for eleven different vehicle-technologies for light-duty commercial vehicles and seven different vehicle-technologies for medium- and heavy-duty commercial vehicles, as shown in Exhibit 2-1, above. Users can select up to four vehicle technologies per vehicle type. Each vehicle is assumed to travel the same distance annually so that value entered is equivalent to the proportion of the VKT travelled by each vehicle technology. The sum of percentages must be 100%.

Defaults values for fleet breakdown are based on national VKT data by vehicle type reported in the Environment Canada MOBILE6.2C output. Assumptions regarding alternative fuel technologies are described in the discussion of Emission Factors.

3.4 Public Transit Vehicles

Buses refer to standard, 40-foot public transit buses. **Trolley Buses** refer to grid-connected public transit buses (e.g., electrically powered from an overhead wire), such as those in service in Vancouver. **Light Rail** is usually driven by electric power taken from overhead lines, such as Toronto streetcars, although it can be diesel-powered (e.g. Ottawa O-train). **Subway/Metro** is electrically powered heavy rail and normally operates underground. **Heavy Rail** refers to diesel-fuelled commuter rail in this application.

ENTER VEHICLE KILOMETRES TRAVELLED BY BUSES

Vehicle kilometres travelled represents the primary input to the Tool for buses and care should be taken to enter accurate values.

ENTER PERCENTAGE OF BUS KILOMETRES IN CITY AND HIGHWAY DRIVING

The proportion of City versus Highway driving is used to estimate fuel efficiency for buses with internal combustion engines (i.e., not Trolley Buses). Default values reflect that all driving for Buses is expected to be in stop and go, city conditions.

ENTER PASSENGER KILOMETRES TRAVELLED BY RAIL VEHICLES

Passenger kilometres travelled represents the primary input to the Tool for rail vehicles, since this measure is a better indicator of rail energy consumption due the variability of rail vehicle size (i.e. the number of cars). Vehicle efficiencies Care should be taken to enter accurate values.

SPECIFY TIME PERIOD FOR ENTERED ACTIVITY DATA

Based on the data available, the user can enter VKT and PKT for the peak hour, average weekday, or annual time period. Travel demand models, available in most larger municipalities, generate travel estimates for the peak hour.   If modelled VKT data are not available, other methods may be used. For example, a transit agency may collect data on daily or annual basis.

MODIFY PUBLIC TRANSIT EXPANSION FACTORS

Expansion factors are used to convert inputted travel data into an annual value. If the user specified that inputted VKT and PKT is daily or annual, the appropriate expansion factors will automatically set to one. Users are encouraged to tailor expansion factors to local conditions. Compared with personal and commercial vehicles, public transit travel has the greatest proportion of daily VKT during the peak hour, when transit demand is highest.

The default value for the peak hour to daily expansion factor takes into account travel characteristics for the Toronto area, a large urban region, based on data from the 2001 Transportation Tomorrow Survey. The default value represents an appropriate expansion factor for buses, light rail, and subways that are used regularly over the course of the day.

A lower peak hour to daily expansion factor would be appropriate for commuter rail given that ridership is highly peaked and commute-trip oriented. For commuter rail in the Toronto area (i.e., GO Transit), the peak hour to daily expansion factor is estimated as 4.5 based on 2001 TTS data.

The daily to annual expansion factor is based on typical transit ridership patterns.

ENTER BUS FLEET BREAKDOWN BY FUEL TECHNOLOGY

The Tool allows for nine different vehicle-technologies for Buses (not including Trolley Buses), as shown in Exhibit 2-1, above. Users can select up to four vehicle technologies per scenario. Each vehicle is assumed to travel the same distance annually so that value entered is equivalent to the proportion of the VKT travelled by each vehicle technology. The sum of percentages must be 100%.

Assumptions regarding alternative fuel technologies are described in the discussion of Emission Factors.

4. EMISSION FACTORS

Factors are used to calculate fuel consumption, GHG emissions, and CAC emissions from annual vehicle travel data, as discussed in the following sections.

One topic, which affects the calculation of all factors, is vehicle classification. Classification of vehicles is typically inconsistent between different sources. Such is the case between the vehicle classifications used for Environment Canada's GHG and CAC reporting, which were the sources of much of the data in this Tool. Exhibit 4-1 shows how the GHG Inventory and Mobile 6.2C vehicle classifications relate and how they were used to determine emission factors for the Tool vehicle types.

Exhibit 4-1: Vehicle Classification by Data Source

UTEC	Environment Canada GHG Inventory	MOBILE 6.2C
LDPV-A	LDGA	LDGV
	LDDA	LDDV
LDPV-T	LDGT	LDGT1
		LDGT2
	LDDT	LDDT12
LDCV	LDGT	LDGT3
		LDGT4
	LDDT	LDDT12
		LDDT34
MDCV	HDGV	HDGV2B
		HDGV3
		HDGV4
		HDGV5
		HDGV6
		HDGV7
	HDDV	HDDV2B
		HDDV3
		HDDV4
		HDDV5
		HDDV6
		HDDV7
HDCV	HDGV	HDGV8A
		HDGV8B
	HDDV	HDDV8A
		HDDV8B
Urban Bus	HDGV	GAS BUS
	HDDV	URB BUS
TB	N/A	N/A
LR-E	N/A	N/A
SM	N/A	N/A
LR-D	Diesel Rail Transportation	N/A
HR	Diesel Rail Transportation	N/A

Note: See Glossary for definition of acronyms.

4.1 Fuel Efficiency

Fuel efficiency factors are used to determine fuel consumption based on annual VKT and PKT values. This fuel consumption is used to calculated direct and indirect GHG emissions. CAC emissions are estimated directly from VKT and PKT.

Fuel efficiency is expressed in L/100 km for most technology types with some variations as shown in the table below.

Exhibit 4-2: Units for Baseline Fuel Efficiency by Vehicle Technology

Vehicle Technology	Fuel Efficiency Units
Unless specified	L/ 100 km
Compressed Natural Gas	m^3/100 km
Electric-Vehicle	MJ/100 km
Plug in Hybrid Electric Vehicle	MJ/100 km
Trolley Bus	MJ/100 km
Light Rail (electric)	MJ/100 p-km
Light Rail (diesel)	L/100 p-km
Subway/Metro (electric)	MJ/100 km
Heavy Rail Diesel	L/100 p-km

For passenger vehicles, commercial vehicles, and buses, fuel efficiency is calculated as a weighted average of City and Highway fuel efficiency factors based on the inputted proportion of kilometres in City and Highway conditions.

CONVENTIONAL ROAD VEHICLE FUEL EFFICIENCY

Baseline fuel efficiencies for gasoline and diesel vehicles for each forecast year were determined based on values from Environment Canada MOBILE6.2C forecasts. These fuel efficiencies take into account the age profile of the fleet by vehicle class at the national scale. Since VKT values were provided for each of the 27 MOBILE6.2C vehicle classes considered, fuel efficiencies for each Tool vehicle type could be calculated as a weighted average of the related MOBILE6.2C vehicle classes as shown in Exhibit 4-1.

Environment Canada MOBILE6.2C forecasts predict only marginal improvements in fuel efficiency over time. Since larger improvements are expected, MOBILE6.2C fuel efficiencies for LDPV, LDCV, MDCV, HDCV, and BUS were scaled by a 0.5% annual improvement factor. This annual improvement rate is on the conservative end of fuel efficiency improvements predicted by NRCan's Emissions Outlook document, which predicts fuel efficiency improvements in the order of 0.5% to 1% per year for most vehicle types.

Another modification to the MOBILE6.2C fuel efficiency results was required to estimate City and Highway fuel efficiencies for each vehicle class. This was a two step process:

1. **Determine the driving conditions assumed in the MOBILE6.2C results**: In developing the Canadian version of the MOBILE6.2 model, MOBILE6.2C, Environment Canada

commissioned a study of to develop speed profiles as input to the model (*Average Speed Estimates for MOBILE6C Emissions Forecasting*, 2003). This study developed a national speed profile based on speed profiles of urban and inter-urban travel for various areas across the country. In analyzing the data used in this study, it was determined that the national speed profile included approximately 31% of VKT under Highway conditions. This included inter-urban travel and approximately 10% of urban travel.

2. **Determine the relationship between City and Highway fuel efficiency**: Based on fuel efficiency ratings for new vehicles, stop and go city driving consumes approximately 20% to 65% more fuel per kilometre than free flow highway driving, varying by vehicle model (Fuel Consumption Guide 2008, Office of Energy Efficiency, Natural Resources Canada, 2007). Based on these results and default City and Highway fuel efficiencies reported in GHGenius, it was assumed that City driving consumes 30% more fuel per kilometre than Highway driving.

Using these values, tables for City and Highway fuel efficiency for diesel and gasoline vehicles were generated from MOBILE6.2C results by horizon year and vehicle class.

ALTERNATIVE TECHNOLOGY ROAD VEHICLE FUEL EFFICIENCY

Fuel efficiencies for alternative technology vehicles were developed based on the relative efficiency factor approach adopted in the GHGenius Tool. Relative efficiency factors provide a basis to determine the fuel efficiency of alternative technology vehicles from known gasoline and diesel-powered vehicle fuel efficiencies of the same vehicle type. GHGenius provides relative efficiency factors for light-duty vehicles and heavy-duty vehicles/transit buses for both City and Highway conditions. Relative efficiency factors for light-duty vehicles were assumed to apply to light-duty passenger and light-duty commercial vehicles. Relative efficiency factors for heavy-duty vehicles were assumed to apply to medium-duty and heavy-duty commercial vehicles as well as buses.

The relative efficiency factor is determined based on the relative efficiency of the alternative fuel/engine combination and the impact on vehicle weight changes on the relative vehicle efficiency. The relative efficiency of the alternative fuel/engine combination is the most important factor. For each alternative technology, relative efficiency is projected to improve with time at a different rate. See Chapter 39 of *Documentation for Natural Resources Canada's GHGenius Model 3.0* (NRCan, 2005), available at www.ghgenius.ca for a more detailed description of the derivation of relative efficiency factors. Relative fuel efficiency factors for alternative technology vehicles are shown in the table below. The factors presented are designed to modify gasoline and diesel fuel efficiency expressed in MJ/km.

Exhibit 4-3: Relative Fuel Efficiency Factors for Alternative Technology Vehicles (MJ/km / MJ/km), Light-Duty Passenger and Light-Duty Commercial Vehicles (relative to Gasoline)

Driving Conditions	Year	P	CNG	LNG	E10	E85	M85	ED10	B100	HYB	PHEV	EV	FC
City	2006	0.98	1.06	0	0.99	0.94	0.95	0	0	0.59	0.44	0.29	0.54
	2011	0.95	1.03	0	0.99	0.93	0.94	0	0	0.57	0.42	0.28	0.53
	2016	0.93	1.01	0	0.99	0.92	0.93	0	0	0.55	0.41	0.27	0.52
	2021	0.93	1.01	0	0.99	0.92	0.93	0	0	0.55	0.41	0.27	0.52
	2026	0.93	1.01	0	0.99	0.92	0.93	0	0	0.55	0.41	0.27	0.52
	2031	0.93	1.01	0	0.99	0.92	0.93	0	0	0.55	0.41	0.27	0.52
Highway	2006	0.98	1.06	0	0.99	0.94	0.95	0	0	0.81	0.6	0.39	0.67
	2011	0.95	1.03	0	0.99	0.93	0.94	0	0	0.78	0.58	0.38	0.64
	2016	0.93	1.01	0	0.99	0.92	0.93	0	0	0.75	0.56	0.37	0.62
	2021	0.93	1.01	0	0.99	0.92	0.93	0	0	0.75	0.56	0.37	0.62
	2026	0.93	1.01	0	0.99	0.92	0.93	0	0	0.75	0.56	0.37	0.62
	2031	0.93	1.01	0	0.99	0.92	0.93	0	0	0.75	0.56	0.37	0.62

Exhibit 4-4: Relative Fuel Efficiency Factors for Alternative Technology Vehicles (MJ/km / MJ/km), Medium-Duty and Heavy-Duty Commercial Vehicles and Transit Buses (relative to Diesel)

Driving Conditions	Year	P	CNG	LNG	E10	E85	M85	ED10	B100	HYB	PHEV	EV	FC
City	2006	1.25	1.26	0.99	0	0	0	1	1	0.61	0	0	0.67
	2011	1.24	1.25	0.98	0	0	0	1	1	0.59	0	0	0.65
	2016	1.23	1.24	0.98	0	0	0	1	1	0.57	0	0	0.64
	2021	1.23	1.24	0.98	0	0	0	1	1	0.57	0	0	0.64
	2026	1.23	1.24	0.98	0	0	0	1	1	0.57	0	0	0.64
	2031	1.23	1.24	0.98	0	0	0	1	1	0.57	0	0	0.64
Highway	2006	1.25	1.26	0.99	0	0	0	1	1	0.84	0	0	0.83
	2011	1.24	1.25	0.98	0	0	0	1	1	0.8	0	0	0.79
	2016	1.23	1.24	0.98	0	0	0	1	1	0.78	0	0	0.77
	2021	1.23	1.24	0.98	0	0	0	1	1	0.78	0	0	0.77
	2026	1.23	1.24	0.98	0	0	0	1	1	0.78	0	0	0.77
	2031	1.23	1.24	0.98	0	0	0	1	1	0.78	0	0	0.77

TROLLEY BUS AND RAIL VEHICLE FUEL EFFICIENCY

Passenger kilometres travelled represents the primary input to the Tool for rail vehicles, since this measure is a better indicator of rail energy consumption due the variability of rail vehicle size (i.e. the number of cars).

Efficiencies for rail vehicles and trolley buses were derived from a variety of sources as outlined:

- Trolley buses: 87 MJ/100 pass-km based on the 2005 APTA Public Transportation Fact Book (average passenger load factor of approximately 13);
- Light Rail (electric): 78 MJ/100 pass-km based on the 2004 APTA Public Transportation Fact Book (average light rail car occupancy of 23.4 passengers);
- Light Rail (diesel): A project summary from the Urban Transportation Showcase Program reports O-train efficiency as 1.32 L/veh-km (http://www.tc.gc.ca/programs/Environment/utsp/otrainlightrailproject.htm). Based on the average light rail car occupancy of 23.4 passengers reported in the 2005 APTA Public Transportation Fact Book, this corresponds to a fuel efficiency of 5.6 L/100 pass-km.
- Subway/Metro (electric): 58 MJ/100 pass-km based on the 2005 APTA Public Transportation Fact Book (average subway/metro car occupancy of 23.4 passengers per car);
- Heavy Rail (diesel): 5.03 L/100 pass-km based on the 2005 results for commuter rail from the Transportation Energy Data Book, Edition 26, Table 9.12, Oak Ridges National Laboratory (average commuter rail car occupancy of 31.4 passengers per car).

4.2 Greenhouse Gas Emission Factors

GHG emissions are estimated based on fuel and electricity consumption from travel. The Tool calculates the GHG emissions from fuel combustion and the upstream fuel cycle effects. *Vehicle operation GHG emissions* are released directly from the tailpipe of a vehicle. *Upstream GHG emissions* are created and released from production of electricity used by electric vehicles (i.e., trolleys and light rail) as well as from the production, refining and transportation of transportation fuels (i.e., from wells to pump). It is important to note that the Tool does not consider life-cycle emissions associated with the manufacture and end-of-life recycling of vehicles.

Global Warming Potential

GHG emissions are calculated for carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) and then reported in CO_2 equivalents (CO_2e) based on their respective global warming potentials. In order to measure the impact of the various gases involved in global warming using a single unit of measurements, the scientific community has adopted a standard based on the impact of one tonne of CO_2 over a 100-year time frame. The impacts of other gas types are compared to CO_2 over the same time frame to produce standard global warming potentials (GWP), expressed in tonnes CO_2 equivalent (CO_2e). GWP values for nitrous oxide and methane are taken from the Canadian GHG Challenge Registry Guide to Entity & Facility-Based Reporting, Version 4.3, 2005 (http://www.ghgregistries.ca/assets/pdf/Challenge_Guide_E.pdf).

Vehicle Operation GHG Emission Factors for Conventional Vehicles

Direct GHG Emission Factors are used to determine the tailpipe GHG emissions of CO_2, N_2O, and CH_4 from urban transportation fuel use. Direct GHG emission factors are measured in g/L except for compressed natural gas, which is measured in g/m^3. Vehicle operation GHG emission factors for conventional vehicles (i.e. gasoline and diesel powered) were provided by Environment Canada in advance of the release of the 1990-2006 Greenhouse Gas Emissions Inventory.

Gasoline and diesel emission factors were taken from the GHG Inventory for each vehicle type as shown in Exhibit 4-1. Since emissions control technology (such as the type of catalytic converter) affects the emission rates of N_2O and CH_4, the fleet penetration of each technology (measured by the age of the fleet) will affect the fleet's overall emission factors. The terminology used by Environment Canada to refer to the most recent and preceding emission control technologies are Tier 1 and Tier 0 for gas-powered vehicles and Advanced Control and Moderate Control for diesel-powered vehicles.

For 2006 road vehicles, emission factors were calculated as a weighted average of Tier 1/Tier 0 and Advanced Control/Moderate Control based on the proportion of the national vehicle fleet built since 1996. This corresponds to the accepted period for vehicles with three-way catalysts or advanced control (Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual). Information of the vehicle fleet composition for light- and heavy-duty vehicles was obtained from the 2006 Annual Canadian Vehicle Fleet Survey published by Statistics Canada. Emission factors for later model years were set to the Tier 1 and Advanced Control values.

GHG Inventory emission factors for Diesel Rail Transportation are used for the light rail-diesel and heavy rail modes.

Vehicle Operation GHG Emission Factors for Alternative Technology Vehicles

Similar to relative efficiency factors discussed earlier, GHG emission factors for alternative technology vehicles were determined using relative emission factors derived from GHGenius. GHGenius uses relative GHG emission factors, which provide a basis to determine CO_2, N_2O, and CH_4 emission factors for alternative technology vehicles from known gasoline and diesel-powered emission factors of the same vehicle type. GHGenius provides relative emission factors for light-duty vehicles and heavy-duty vehicles/transit buses. Relative emission factors for light-duty vehicles were assumed to apply to light-duty passenger and light-duty commercial vehicles. Relative efficiency factors for heavy-duty vehicles were assumed to apply to medium-duty and heavy-duty commercial vehicles as well as buses. The approach and sources used in determining these relative emission factors are described in Chapter 40 of *Documentation for Natural Resources Canada's GHGenius Model 3.0* (NRCan, 2005), available at www.ghgenius.ca.

Relative GHG emission factors for alternative technology vehicles are shown in the table below.

Exhibit 4-5: Relative GHG Emission Factors for Alternative Technology Vehicles

Vehicle Type	GHG	P	CNG	LNG	E10	E85	M85	ED10	B100	HYB	PHEV	EV	FC
LDPV, LDCV	CO2	0.66	0.85	0.00	0.90	0.16	0.56	0.00	0.00	1.00	1.00	0.00	0.49
	CH4	0.75	19.42	0.00	1.01	1.14	0.39	0.00	0.00	1.00	1.00	0.00	0.61
	N20	0.75	0.31	0.00	0.39	0.61	0.25	0.00	0.00	1.00	1.00	0.00	0.00
MDCV, HDCV, BUS	CO2	0.57	0.71	0.53	0.00	0.00	0.00	0.90	0.01	1.00	0.00	0.00	0.40
	CH4	0.52	11.73	8.75	0.00	0.00	0.00	0.96	0.96	1.00	0.00	0.00	0.00
	N20	0.53	0.78	0.59	0.00	0.00	0.00	0.96	0.96	1.00	0.00	0.00	0.00

Note: Factors for LDPV/LDCV are relative to gasoline emission factors of the same vehicle type, factors for MDCV/HDCV/BUS are relative to dieses emission factors of the same vehicle type.

All electric vehicles have no direct GHG emissions. Hybrid vehicle emission factors are assumed to be the same per litre as the primary fuel (e.g., gas for LDPV, diesel for BUS) for the vehicle type under consideration.

Upstream Fuel Cycle GHG Emission Factors

Upstream fuel cycle GHG emission factors are used to estimate the 'upstream' fuel cycle GHG emissions associated including fuel refining and transportation. They are fuel specific and were determined from GHGenius. GHGenius estimates the GHG emissions in CO_2 equivalents from fuel dispensing, fuel distribution and storage, fuel production, feedstock transmission, feedstock recovery, land use changes, fertilizer manufacture, gas leaks and flares, and emissions displaced. Default results are used, which represent average industry conditions in Canada. There are many assumptions involved in these calculations, such as the distance the fuel is transported and the fuel feedstock. The user should refer to GHGenius (www.ghgenius.ca) if detailed analysis of upstream GHG emissions is required.

The feedstock for the ethanol in E10, E85, and ED10 is assumed to be corn. The feedstock for biodiesel is assumed to be soybeans. The fuel cells are assumed to run on methanol.

Indirect Electricity Production GHG Emission Factors

Indirect electricity production GHG emission factors are used to determine the GHG emissions associated with electric vehicles. They are specified in kg CO2e/MJ of electricity consumed. The factors are province and territory-specific based on the mix of electricity generation methods in each region. These factors were determined from the electricity GHG emission factors reported in the 1990-2005 (see http://www.ec.gc.ca/pdb/ghg/inventory_report/ 2005_report/tdm-toc_eng.cfm) by province and territory. Forecasts of electrical emission factors are not available so the factors do not change over the model years.

4.3 Criteria Air Contaminant Emission Factors

Vehicle Operation CAC Emission Factors for Conventional Vehicles

CAC emission factors are used to determine the emissions of carbon monoxide (CO), nitrogen oxides (NO_X), sulphur dioxide (SO_2), volatile organic compounds (VOCs), total particulate matter (TPM), particulate matter less than 10 microns in diameter (PM_{10}), and particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) from vehicle operation. Direct CAC emission factors have the units of g/km as they are better estimated by distance travelled than by amount of fuel consumed.

Direct CAC emission factors for conventional vehicles were developed from forecasts of CAC emission factors from MOBILE6.2C developed by Environment Canada. These factors were estimated based on national speed profiles developed from urban and inter-urban travel (Average Speed Estimates for MOBILE6C Forecasting, Environment Canada, 2003) CAC emission factors are very sensitive to driving conditions and driving speed, in particular. As such, if the speed profile of the fleet under consideration is substantially different from the national average, CAC emission estimations will be less accurate.

MOBILE6.2C estimates emission factors for CO, NO_X, SO_2, VOC, as well as particulate matter (TPM, PM_{10}, and $PM_{2.5}$) from fuel combustion and brake and tire wear. Emission factors were provided by Environment Canada for all the model years for the 27 vehicle classifications shown in Exhibit 4-1. Substantial improvements in CAC emission factors are forecast over time. Since VKT values were provided for each of the 27 MOBILE6.2C vehicle classes considered, emission factors for each Tool vehicle type could be calculated as a weighted average of the related MOBILE6.2C vehicle classes.

CAC emission factors for diesel-powered rail were taken from the 2005 Locomotive Emissions Monitoring Program Report (Environment Canada, http://www.railcan.ca/documents/publications/1436/2007_03_20_LEM2005_en.pdf). Emission factors are provided for CO, NO_X, SO_2, VOC, and TPM.

Vehicle Operation CAC Emission Factors for Alternative Technology Vehicles

CAC emission factors for alternative technology vehicles were determined using relative emission factors derived from GHGenius. GHGenius uses relative CAC emission factors, which provide a basis to determine CO, NO_X, SO_2, VOCs, and TPM emission factors for alternative technology vehicles from known gasoline and diesel-powered emission factors of the same vehicle type. GHGenius provides relative emission factors for light-duty vehicles and heavy-duty vehicles/transit buses. Relative emission factors for light-duty vehicles were assumed to apply to light-duty passenger and light-duty commercial vehicles. Relative emission factors for light-duty vehicles were assumed to apply to light-duty passenger and light-duty commercial vehicles. Relative efficiency factors for heavy-duty vehicles were assumed to apply to medium-duty and heavy-duty commercial vehicles as well as buses.

The particulate matter multiplication factor was assumed to apply to all particulate emission factors (TPM, PM_{10}, and $PM_{2.5}$).

For electric road vehicles, the CO, NO_X, SO_2, and VOC emissions were assumed to be zero; however, even though these vehicles have no exhaust, they do generate particulate matter emissions from brake and tire wear. Based on MOBILE6.2C factors for gas and diesel vehicles, the average proportion of TPM, PM_{10}, and $PM_{2.5}$ emissions from brake and tire wear was determined for each vehicle type. These values were used as multiplication factors to determine particulate matter emissions from road-based electric vehicles.

CAC multiplication factors are displayed in the table below. The approach and sources used in determining these relative emission factors are described in Chapter 40 of *Documentation for Natural Resources Canada's GHGenius Model 3.0* (NRCan, 2005), available at www.ghgenius.ca.

Exhibit 4-6: Relative CAC Emission Factors for Alternative Technology Vehicles

Vehicle Type	CAC	Vehicle Technology											
		P	CNG	LNG	E10	E85	M85	ED10	B100	HYB	PHEV	EV	FC
LDPV	CO	0.6	0.26	-	0.97	0.68	0.7	-	-	0.64	0.32	0	0
	NOx	0.9	1.09	-	0.99	0.92	0.93	-	-	0.64	0.32	0	0
	SO2	0.19	0.13	-	0.3	0.03	0.28	-	-	0.17	0.09	0	0.02
	VOC	0.27	0.12	-	0.97	0.68	0.48	-	-	0.64	0.32	0	0.02
	TPM	0.25	1.68	-	0.96	0.52	0.55	-	-	0.64	0.32	0.6	0.6
	PM10	0.25	1.68	-	0.96	0.52	0.55	-	-	0.64	0.32	0.6	0.6
	PM2.5	0.25	1.68	-	0.96	0.52	0.55	-	-	0.64	0.32	0.42	0.42
LDCV	CO	0.6	0.26	-	0.97	0.68	0.7	-	-	0.64	0.32	0	0
	NOx	0.9	1.09	-	0.99	0.92	0.93	-	-	0.64	0.32	0	0
	SO2	0.19	0.13	-	0.3	0.03	0.28	-	-	0.17	0.09	0	0.02
	VOC	0.27	0.12	-	0.97	0.68	0.48	-	-	0.64	0.32	0	0.02
	TPM	0.25	1.68	-	0.96	0.52	0.55	-	-	0.64	0.32	0.4	0.4
	PM10	0.25	1.68	-	0.96	0.52	0.55	-	-	0.64	0.32	0.4	0.4
	PM2.5	0.25	1.68	-	0.96	0.52	0.55	-	-	0.64	0.32	0.28	0.28
MDCV/ HDCV	CO	0.01	0.01	0.01	-	-	-	0.85	0.05	0.61	-	-	-
	NOx	0.4	0.24	0.24	-	-	-	1	0.88	0.61	-	-	-
	SO2	0.72	0.5	0.5	-	-	-	0.9	0.88	0.61	-	-	-
	VOC	2.26	0.74	0.74	-	-	-	0.83	0.23	0.61	-	-	-
	TPM	0.01	0.06	0.06	-	-	-	0.8	0.07	0.61	-	-	-
	PM10	0.01	0.06	0.06	-	-	-	0.8	0.07	0.61	-	-	-
	PM2.5	0.01	0.06	0.06	-	-	-	0.8	0.07	0.61	-	-	-
BUS	CO	0.01	0.01	0.01	-	-	-	0.85	0.05	0.61	-	-	0
	NOx	0.4	0.24	0.24	-	-	-	1	0.88	0.61	-	-	0
	SO2	0.72	0.5	0.5	-	-	-	0.9	0.88	0.61	-	-	0
	VOC	2.26	0.74	0.74	-	-	-	0.83	0.23	0.61	-	-	0.31
	TPM	0.01	0.06	0.06	-	-	-	0.8	0.07	0.61	-	-	0.29
	PM10	0.01	0.06	0.06	-	-	-	0.8	0.07	0.61	-	-	0.29
	PM2.5	0.01	0.06	0.06	-	-	-	0.8	0.07	0.61	-	-	0.14

Note: Factors for LDPV/LDCV are relative to gasoline emission factors of the same vehicle type, factors for MDCV/HDCV/BUS are relative to dieses emission factors of the same vehicle type.

5. RESULTS

The Tool output screen summarizes the annual travel and related GHG and CAC emissions. The output screen is structured so that it can be easily copied and pasted into a spreadsheet program, such as Excel. This allows the user to store results from different scenarios and compare and analyze the results as they see fit.

GHG AND CAC EMISSIONS

The output summarizes annual vehicle operation and upstream GHG emissions in unit of mass of CO_2e. The output also summarizes annual CAC emissions by contaminant.

ANNUAL TRAVEL

The output summarizes annual vehicle kilometres travelled for road vehicles and annual passenger kilometres travelled for rail vehicles.

6. GLOSSARY

B100	-	100% biodiesel (100% soybean feedstock assumed)
Bus	-	Urban public transit bus
CAC	-	Criteria air contaminant (CO, NOx, SO_x, VOC, TPM, PM_{10}, $PM_{2.5}$)
CNG	-	Compressed natural gas
CO_2e	-	Carbon dioxide equivalents – Single unit describing the global warming potential of all GHG emissions.
D	-	Diesel
E10	-	10% ethanol/ 90% gasoline blend (ethanol is assumed to be derived from corn feedstock)
E85	-	85% ethanol/ 15% gasoline blend (ethanol is assumed to be derived from corn feedstock)
EV	-	Electric vehicle
ED10	-	10% ethanol/ 90% diesel blend (ethanol is assumed to be derived from corn feedstock)
FC	-	Fuel cell (methanol derived from natural gas is assumed as the hydrogen source)
G	-	Gasoline
GHG	-	Greenhouse gas
GWP	-	Global warming potential – Global warming impact of a gas compared to CO_2 over a 100-year time frame.
HDCV	-	Heavy-duty commercial vehicle
HR	-	Heavy rail (diesel powered)
HYB	-	Hybrid-electric vehicle (gasoline fuel is assumed for LDPV and LDCV hybrids and diesel fuel is assumed for Bus hybrids)
LDCV	-	Light-duty commercial vehicle
LDPV	-	Light-duty passenger vehicle
LDPV-A	-	Light-duty passenger automobile
LDPV-T	-	Light-duty passenger truck (minivan, SUV, light truck)
LNG	-	Liquefied natural gas
LR-D	-	Light rail (diesel powered)
LR-E	-	Light rail/Metro (electrically powered)
M85	-	85% methanol/ 15% gasoline blend (methanol is assumed to be derived from natural gas)
MDCV		Medium-duty commercial vehicle

NG	-	Natural gas
P	-	Propane
PHEV	-	Plug-in hybrid electric vehicle (PHEV50/50 assumed meaning that the battery can provide energy for 50km of driving and vehicle operates in battery mode for 50% of driving)
PKT	-	Passenger kilometres travelled
SM	-	Subway/Metro
TB	-	Trolley bus (electrically powered from an overhead wire)
VKT	-	Vehicle kilometres travelled