Transport Canada Transports Canada

TP 14929E

EMISSION ESTIMATION TOOLS

REFERENCE GUIDE

ENVIRONMENTAL INITIATIVES

OTTAWA, ONTARIO

REPORT

SEPTEMBER 2009

Canada

Please direct your comments and inquiries to:

Eric Sévigny, Manager
Urban Transportation Programs
Environmental Initiatives
Transport Canada
Place de Ville, 330 Sparks St.
Ottawa, Ontario K1A 0N5
E-mail: urban-urbain@tc.gc.ca
Website: www.tc.gc.ca/urban

TP: 14929E

TC: T42-1/2009E-PDF

ISBN: 978-1-100-14054-4

*Cette publication est aussi disponible en français sous le titre [*Guide des outils d'estimation des émissions*].*

An electronic version of this publication is available at [http://www.tc.gc.ca/eng/programs/environment-urban-menu-eng-1794.htm].

Canada

1. INTRODUCTION

IBI Group was commissioned by Transport Canada to conduct a review of emissions calculation tools available to transportation professionals, with the objective of improving government decision-making capacity in the area of GHG mitigation in the urban transportation sector

This report provides a short reference guide for public distribution on available tools for estimating emissions from transportation and a process for deciding when and how they should be used. After using this report, users should end up with a short-list of tools that might be suitable for their requirements.

This document contains three chapters and an appendix, with this introduction forming chapter one. Chapter two provides a brief overview of how transport emissions are typically estimated, and also provides information on how this relates to air quality. Chapter three looks at tool classification criteria, specifically user type, scale, modes and outputs. Each section within the chapter explains the possible options and provides a list of suitable tools. The information is summarised in the form of a table at the end of the chapter. The appendix provides basic information on each of the tools referenced in this guide, including price details and where to find out more information.

2. TYPICAL EMISSIONS ESTIMATION PROCESS

To estimate emissions of any type from transport, the object is to go from some measure of usage to an amount of substance emitted. The measure of usage is normally considered separate for each mode, but may be refined further by vehicle type (for example, splitting road vehicles into passenger cars, trucks and SUVs). The usage may be measured simply in terms of vehicle-kilometres travelled (VKT), or it may include vehicle hours, or even a breakdown into different speed categories and road type. The level of usage forms the main input into all the tools considered here.

In general, emissions result directly from fuel consumption, so most models turn the usage patterns into fuel consumption, which is then turned into emissions levels. However, emissions are also produced from tire wear (particulate matter) and during refuelling (VOCs[1]). Some tools do this as a single step, using simple emission factors (for example, grams of CO_2 per 100 km). Others will contain parameters adjusting fuel consumption, fuel type and vehicle efficiency, to produce a more precise measure of fuel consumption.

2.1 Emissions and air quality

Once emission levels have been calculated, the data can be used for one of two purposes: greenhouse gas effects and air quality impacts. Although transport professionals may be required to calculate greenhouse gas emissions to a high degree of precision and accuracy, the main intent is almost always to see whether they increase or decrease. The climatic impacts of a given level of emissions generally fall outside the transportation profession's scope.

On the other hand, the impact on air quality resulting from a given transport scenario is often required, not least due to the potential health and quality of life impacts from certain pollutants. This is a complicated process, because the levels of emissions typically vary by time place, and the impacts of a given pollutant concentration will also vary by external factors, such as climate. Normally, an air quality model will take account of local topography, prevailing climate, the transport network layout, and emissions profile by time and place. The local geography and climate dictate how emissions spread from their source, and this can be combined with the emissions sources by time and place to produce the air quality in a given place. Examples of air quality models include CAL3QHC, ISC3 and AERMOD.

Air quality models are not considered here, but this report does discuss the level of detail provided by the emissions calculation tools so that suitable tools can be selected.

[1] Volatile organic compounds – see section 3.4.2 for details.

3. TOOL CLASSIFICATION CRITERIA

This chapter provides a detailed examination of tool classification criteria, looking at user type, scale, modes and outputs. Each section explains the possible options and provides a list of suitable tools. The information is summarised in the form of a table at the end of the chapter.

3.1 User Type

The first aspect to consider when selecting an emission tool is the type of user – who the results are intended for. The tools required for input into policy decisions would be different from those required for an air quality model. In general, the choice is between tools that can evaluate the broad trend, compared with those that provide a high degree of precision in order to produce exact estimates of emissions levels.

3.1.1 POLICY DECISION

Tools aimed at policy decisions seek to establish broad trends from a given scenario, rather than exact figures. The results from these tools tend to be useful to policy makers, so they can establish a broad course of action rather than analysing the detailed results of specific actions. Often the desired output may be as simple as to whether there is an increase or decrease in emissions.

Suitable tools for general policy decisions: CCAP, CMHC Greenhouse Gas Emissions from Urban Transit, CMHC Life Cycle Costing Tool, FLEET, GREET, IPCC Software, SATURN

3.1.2 SPECIFIC ESTIMATES AND OPTION EVALUATION

The other class of tool are those that focus on providing precise estimates of the level of emissions. Typically, these tools may be used to compare a number of options for potential transport schemes, and see which has the best outcome. The level of detail required in the inputs reflects what options the tools are designed to compare. For example, those aimed at evaluating different fuel sources will require detail on the usage split between different fuel types, whereas other models will apply some representative values.

Suitable tools for specific estimates and option evaluation: CMEM, CORSIM, EMFAC, IPCC Software, Mobile6.2C, SATURN, TravelMatters: Individual Emissions Calculator, TravelMatters: Transit Planning Calculator, UTEC, VISSIM

Included within this category are those tools that are designed to compare the effects of using different types of fuel. This can include the split between different vehicle types (such as gasoline, diesel, hydrogen or electric); or how the energy source in the car is produced (biofuels vs. oil-derived; or electricity generation mix).

Suitable tools for comparing fuels: GHGenius, GREET

3.2 Scale

The second aspect to consider is the scale of the model – how big a geographic area is being modelled. This section looks at four scale classes, from largest to smallest.

3.2.1 REGIONAL OR BROADER

The broadest tools cover regions, provinces/states, and countries. These tools tend not to model individual roads or transit routes, but use aggregated totals for vehicle-kms or passenger-kms as their key input. They may model mode split (either for passenger or freight), or other general issues such as fuel sources, types, and consumption.

Suitable tools: GHGenius, GREET, IPCC Software, UTEC

3.2.2 MUNICIPAL

Municipality-scale tools aim to cover en entire city, or sometimes a small group that are in close proximity. Where these tools are aimed at road emissions, they will typically model arterial and collector roads, but not local access roads. Those tools aimed at public transit will model all routes operating within the given area, but may not account for minor route variations (such as terminating the last run of the day before the usual end point). Although overall transport demand is generally fixed, these tools generally take account of route choices.

Suitable tools: CCAP, CMHC Greenhouse Gas Emissions from Urban Transit, CMHC Life Cycle Costing Tool, SATURN, TravelMatters: Individual Emissions Calculator, UTEC

3.2.3 CORRIDOR

A transport corridor is where a number of routes run concurrently. Major highways tend to act as corridors, with road trips to and from destinations near the highway using it, even when parallel routes might exist. Similarly, public transit routes often converge on a particular street due the large number of trips induced by the land use along it. Improvements along a corridor tend to have a higher potential for wider benefits due to the number of trips involved. Most tools capable of modeling at the corridor scale are road based, and are able to model a series of intersections and junctions, and how their features combine to affect traffic flow (whether truck, automobile or transit). This scale is at the boundary between microsimulation (where individual vehicles are modelled) and macrosimulation (where the model deals with vehicle flow rates).

Suitable tools: CCAP, CMHC Greenhouse Gas Emissions from Urban Transit, CMHC Life Cycle Costing Tool, SATURN, TravelMatters: Individual Emissions Calculator, VISSIM

3.2.4 LOCAL AREA

The most detailed level of tools model local areas. This can be as small as an individual intersection, or may include a neighbourhood. An example might compare possible street patterns to find the right balance between the short travel distance provided by a grid system, and the better flow resulting from a dendritic (tree-like) layout. Another example might be trying to find the balance between being optimised for automobile travel (which produces the bulk of emissions) and ease of public transit access (which has potential to reduce automobile emissions).

Suitable tools: CCAP, TravelMatters: Individual Emissions Calculator, VISSIM

3.3 Modes

Different modes of transport have different emissions patterns, and also affected by different policies. Normally, the split between modes is handled separately to the emissions calculation process. The reason is that the *total* level of emissions from a given mode rarely affects its desirability; whereas the total usage does (high congestion of levels of crowding reduces desirability). So, tools take the level of usage for a given mode, at whatever level of detail it is defined, and use it to calculate emissions.

3.3.1 AUTOMOBILE

Tools that model personal automobile use are very common, as this represents both the biggest single source of transport emissions, and the one that is most susceptible to change. Where the tools model individual roads, these tools will account of the range of route options for any journey. Regardless of the scale being modelled, the overall automobile demand forms the key input into these tools. The biggest difference between the different tools designed to model automobile emissions are the scale at which they operate (see previous section for details)..

Suitable tools for automobile use: CCAP, CMHC Greenhouse Gas Emissions from Urban Transit, CORSIM, GHGenius, GREET, IPCC Software, Mobile6.2C, TravelMatters: Individual Emissions Calculator, UTEC, VISSIM

3.3.2 PUBLIC TRANSIT

Although public transit generally results in lower levels of emissions per passenger-km than personal automobile use, there is often a need to calculate transit emissions to calculate accurately the results of a mode shift. Generally, tools that are also capable of modelling automobile use are able to produce travel times, which can be used when planning bus routes to determine the size of fleet required. This in turn directly affects the annual amount of vehicle-kms for the transit fleet.

Suitable tools for public transit – general estimates: CCAP, CMHC Greenhouse Gas Emissions from Urban Transit, CORSIM, IPCC Software, Mobile6.2C, TravelMatters: Individual Emissions Calculator, UTEC, VISSIM

A more specialised use is for calculating the effects of transit using different fuels and vehicle types. This might include switching from regular fuel to biofuels, or use of hybrid engines.

Suitable tools for public transit – fuel or fleet variations: CCAP, GHGenius, TravelMatters: Individual Emissions Calculator, UTEC

3.3.3 ROAD FREIGHT

Road freight may be modelled as part of general road emissions, or separately. Many road modelling tools aimed at automobile usage are able to include trucks as an additional vehicle type. Options that more detailed tools model might include changes to driver habits (such as reducing idling), changes to fleet mix (such as using a mix of vehicle sizes to maximise load factors), or vehicle improvements (such as aerodynamic improvements).

Suitable tools: CCAP, CORSIM, GHGenius, FLEET, GREET, IPCC Software, Mobile 6.2C, UTEC, VISSIM

3.3.4 OTHER MODES

Other transport modes that produce emissions are air, rail and marine transport. Tools that model these modes are relatively rare. The *TravelMatters* tool can model per person emissions of rail, marine and air transport. The *IPCC Software* can model emissions given the aggregate annual fuel consumption (by fuel type) for the different modes.

Suitable tools for other modes: IPCC Software, TravelMatters: Individual Emissions Calculator

3.4 Outputs

This section lists the various types of emissions produced by transport, and explains their effects and the principal means for reducing their rate of emission from transport sources.

3.4.1 GREENHOUSE GAS EMISSIONS (GHG)

Greenhouse gases are those that contribute to global warming by increasing the earth's "greenhouse effect" (the proportion of the sun's energy that stays within the atmosphere rather than being radiated out into space). By the far the most important greenhouse gas is **carbon dioxide (CO_2)**, which results from the burning of any fossil fuel or, in fact, any fuel derived from organic matter. Those fuels produced from recently grown plants are known as biofuels. There is a key difference between burning fossil fuels and burning biofuels. Fossil fuels release CO_2 into the atmosphere that was burned millions of years ago, resulting in an increase in the amount of CO_2 in the atmosphere. On the other hand, biofuels release CO_2 trapped by the plants relatively recently, resulting in no net change in the amount of CO_2 over the course of a decade. However, the energy produced in their production may outweigh the potential gains.

Because burning any fuel releases CO_2, the only ways to reduce transport emissions CO_2 are as follows:

- keep the split between modes the same, but make a mode or modes more produce less CO_2 (such as being more fuel efficient or deriving their energy through alternative means); or
- alter the mode split in favour of less CO_2 intensive modes (such as more people using public transit, or shifting freight from road to rail); or
- reduce transport demand.

Two other significant greenhouse gases resulting from transport emissions are **methane (CH_4)** and **nitrous oxide (N_2O)**. Nitrous oxide is also considered to be a criteria air contaminant (CAC) due to its health impacts. Although these gases are produced in significantly smaller quantities than CO_2, they produce a bigger change to the greenhouse effect on a per ton basis. In order to capture the combined effects in a single figure, the term **carbon dioxide equivalent (CO_2e)** is used. This represents the amount of carbon dioxide that would produce the equivalent effect of the mixture of greenhouse gases being emitted. Most greenhouse gases decompose into other substances once in the atmosphere, meaning that their greenhouse effect changes over time. Therefore, CO_2e is evaluated over some specific time period, normally 100 years. On this timescale, one ton of methane is equivalent to 25 tons of CO_2, and one ton of nitrous oxide is equivalent to 298 tons of CO_2.

3.4.2 CRITERIA AIR CONTAMINANTS (CAC) AND OTHER POLLUTANTS

3.4.2.1 Criteria Air Contaminants (CAC)

Environment Canada defines a number of substances to be **Criteria Air Contaminants (CAC)**. These are a number of substances known to cause smog, acid rain and general health hazards, such as respiratory problems. Transport is one source of CAC emissions, with agriculture, industry, mining, and electricity generation also being major sources. The last couple of decades have seen efforts by many governments to set emissions standards for transport (especially cars and trucks) and other sources in order to reduce emissions. The six classes of CAC emissions are:

- **Sulfur oxides (SO_x):** These gases are a major cause of acid rain, due to their reaction with atmospheric water to produce sulfuric acid. It can also contribute to smog. In transport, their emissions result from traces of sulfur within fuels. Reduction in the rate of SO_x emissions from transport is achieved by reducing the amount of sulfur in fuels.

- **Nitrogen oxides (NO_x):** These gases are also a cause of acid rain, due to their reaction with atmospheric water to produce nitric acid. It can also contribute to smog. They also aggravate respiratory problems. Their emissions from transport result from nitrogen from the atmosphere combining in an engine due to the high temperatures inside. Reduction in the rate of NO_x emissions from transport is achieved through the use of catalytic converters, which are mandatory in an increasing number of jurisdictions.

- **Particulate matter (PM):** This is a catch-all term covering any solid matter of sufficiently small particle size that it is able to remain in the atmosphere indefinitely (or until washed out by rain). It can contribute to smog. Particulate matter may be classified by particle size, with **PM_{10}** and **$PM_{2.5}$** being the most common, and referring to the amount of particulate matter less than 10 and 2.5 microns in diameter respectively. The term **total particulate matter (TPM)** is also used. Transport emissions of particulate matter are generally carbon (in the form of soot) resulting from unburnt fuel, and the rate of emission is generally reduced by better engine design (which also leads to better fuel efficiency).

- **Volatile organic compounds (VOC):** This is another catch-all term, covering all organic compounds (those that contain carbon) which are able to exist as a vapour in normal atmospheric conditions. Transport emissions of VOC generally result from fuel or additives not being burnt completely within the engine, and so the rate of emission is generally reduced by better engine design.

- **Carbon monoxide (CO):** This is a toxic gas, which can aggravate respiratory problems. It decays in the atmosphere to CO_2, so it may be included with CO_2 when calculating GHG emissions, although the relative amount of carbon monoxide is generally small. Transport emissions of CO_2 result from partially oxidised fuel, and can be reduced by improved engine design (which will increase fuel efficiency).

- **Ammonia (NH_3):** a mildly toxic gas, which can aggravate respiratory problems. It is highly soluble in water, and thus can cause contamination to waterways when washed out of the atmosphere by rain. Transport emissions of ammonia are insignificant.

3.4.2.2 Other pollutants

In addition to the pollutants mentioned above, a few tools also model some other pollutants, which are generally included in the above. These include **benzene** (very toxic, especially in waterways and groundwater, otherwise included in VOC); **hydrocarbons** (varying degrees of toxicity, would otherwise be included in VOC or PM); **2-Methoxy-2-methylpropane (MBTE)** (used to make tires, toxic in groundwater, otherwise included in VOC); **Lead (Pb)** (toxic, causes brain problems); and **sulfur dioxide (SO_2)** (normally included in SO_x due to having the same effects). One tool also produces results for methanal (formaldehyde), 2-propenal (acrolein), ethanal and 1,3-Butadiene.

3.5 Summary table

The table on the next page provides a summary of the information contained in this chapter. Tools are listed alphabetically down the left-hand side, and the various selection criteria are listed along the top. Each row contains ticks (✓) to indicate which criteria the tool fulfills.

TOOL	USE			SCALE				MODES						EMISSION OUTPUTS																	
														Greenhouse gases				Criteria air contaminants and other pollutants													
	Policy Decision	Specific Estimates	Fuel comparison	Regional	Municipality	Corridor	Local Area	Automobile	General transit	Bus	Other transit	Road freight	Other	CH_4 (methane)	CO_2	CO_2e	CO	Benzene	Hydrocarbons	MBTE	NH_3 (ammonia)	NO_x ($NO + NO_2$)	N_2O	$PM_{2.5}$	PM_{10}	Pb (lead)	SO_2	SO_x	TPM	VOC	Other (see below)
CCAP Guidebook Emissions Calculator	✓				✓	✓	✓	✓	✓		✓	✓			✓		✓				✓	✓	✓	✓	✓		✓			✓	
CMEM (Comprehensive Modal Emissions Model)		✓																													
CMHC Greenhouse Gas Emissions from Urban Transit	✓				✓	✓		✓	✓							✓															
CMHC Life Cycle Costing Tool	✓				✓	✓																									[1]
CORSIM		✓						✓		✓		✓					✓		✓			✓									
EMFAC																															
Freight Logistics Environment and Energy Tracking (FLEET) Performance Models		✓																													
GHGenius		✓	✓	✓				✓		✓		✓		✓	✓		✓					✓	✓	✓	✓						
GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation)	✓	✓	✓	✓				✓				✓		✓	✓		✓					✓	✓	✓	✓			✓		✓	
IPCC Software for National Greenhouse Gas Inventories	✓	✓		✓				✓	✓			✓	✓			✓															
Mobile6.2C		✓						✓		✓		✓			✓		✓	✓	✓	✓		✓				✓	✓				[2]
SATURN	✓	✓																													
TravelMatters: Individual Emissions Calculator		✓			✓	✓	✓	✓	✓		✓		✓		✓		✓					✓								✓	
TravelMatters: Transit Planning Calculator		✓																													
Urban transport emissions calculator (UTEC)		✓		✓	✓	✓		✓	✓		✓	✓				✓	✓					✓		✓	✓						
VISSIM		✓				✓	✓	✓			✓	✓			✓		✓					✓							✓		

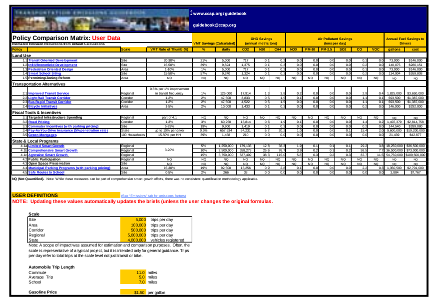
Notes

[1] Tool just provides a measure of "air pollution"
[2] Tool also provides emissions levels of methanal, 2-propenal, ethanal and 1,3-Butadiene.

4. TOOL INFORMATION

This chapter provides basic information on each of the tools referenced in this guide. Tools are ordered alphabetically.

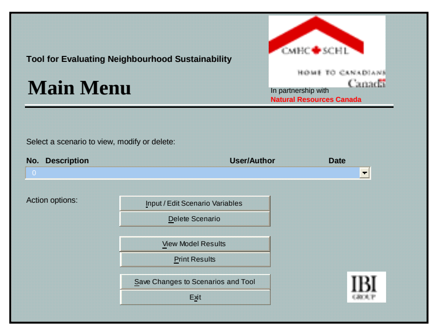
4.1.1 CCAP GUIDEBOOK EMISSIONS CALCULATOR



The Center for Clean Air Policy (CCAP), a Washington DC-based international organisation, created the Guidebook Emissions Calculator to calculate emissions reductions from the implementation of specific transportation and land use policies. The tool comes in two parts, with the first modeling land use, transit and travel demand management, and the second modelling vehicle technology and fuels. The tool is freely available via the CCAP website (http://www.ccap.org/safe/guidebook/guide_complete.html). It was the only tool reviewed that was specifically designed to model government policy impacts.

Main inputs: Land use profile, transit improvements, road pricing, green policy levels, green taxes, emissions standards, fleet composition, driver education.	**Main outputs:** Emission factors (g/veh-mile) for CO_2, CO, NO_x, SO_2, VOC, NH_3, CH_4, N_2O, PM_{10} and $PM_{2.5}$ for current and future years.
Strengths: Able to model wide range of policies, unique capabilities.	**Weaknesses:** Difficulty in quantifying effects of policy leads to inherent uncertainty in results.

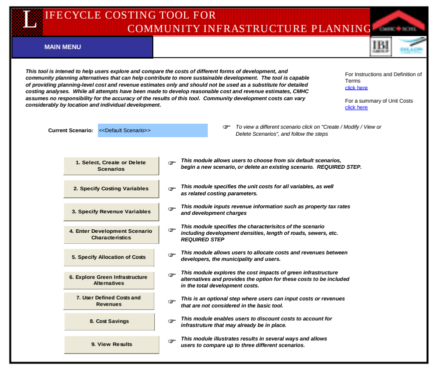
4.1.2 CMHC GREENHOUSE GAS EMISSIONS FROM URBAN TRANSIT



The Canadian Mortgage and Housing Corporation (CMHC) created this tool to look at the emissions generated by urban travel resulting from a given land use. The tool was based on a study of the Greater Toronto area, although it is intended for application in any city. It is capable of estimating the impacts of factors such as land use density, employment accessibility. The tool is implemented in Microsoft Excel and is available for free from the CMHC website (http://www.cmhc-schl.gc.ca/en/inpr/su/sucopl/grgaem/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=159738)

Main inputs: Distance to CBD, Predicted vehicles/household, Transit VSH locally, housing density, persons per household, local employment density, local retail levels, rapid transit and commuter rail provision.	**Main outputs:** Weekday auto and transit VKT; CO_2e from auto and transit.
Strengths: Ease of use, takes account of different transit modes	**Weaknesses:** Lack of detail

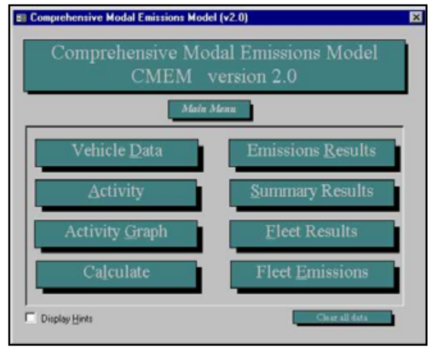
4.1.3 CMHC LIFE CYCLE COSTING TOOL



The Canadian Mortgage and Housing Corporation (CMHC) created the Life Cycle Costing tool to look at the total cost associated with a particular land use development. It focuses primarily on hard infrastructure, but does include a small emissions element. The tool is implemented in Microsoft Excel and is available for free from the CMHC website (http://www.cmhc.ca/en/inpr/su/sucopl/licycoto/).

Main inputs: Land use profile; unit costs of hard infrastructure, municipal services, private User Costs (driving and home heating costs), and external costs (air pollution, climate change and motor vehicle collisions).	**Main outputs:** Major costs of community development, particularly those sensitive to the form of development.
Strengths: Able to take account of green infrastructure alternatives	**Weaknesses:** Emissions are a sideline to financial costs

4.1.4 CMEM (COMPREHENSIVE MODAL EMISSIONS MODEL)

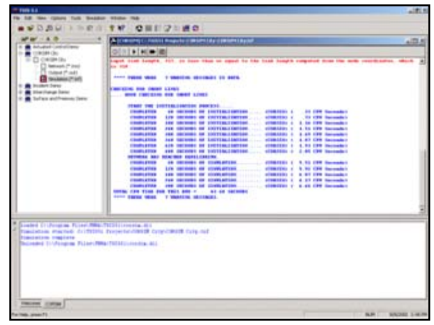


The Comprehensive Modal Emissions Model (CMEM) was created in 2001 under the guidance of the United States' National Cooperative Highway Research Program to model light-duty vehicle emissions as a function of the vehicle's operating mode. It is a stand-alone nanosimulation model, able to predict emissions for a wide variety of LDVs in various states of condition (e.g. properly functioning, deteriorated, malfunctioning), and is capable of predicting second-by-second tailpipe emissions and fuel consumption for a wide range of vehicle/technology categories. The tool can run in batch mode to compile the results of multiple vehicles. The tool costs $20, and is available from the website of the University of California, Riverside (http://pah.cert.ucr.edu/cmem/).

Main inputs: Vehicle characteristics (including mass, engine size and power, torque information, idle speed and number of gears), operating environment (including road grade, accessory power, speed trace, soak time and humidity) and activity profile (velocity, acceleration, road grade and secondary power load by time period).	**Main outputs:** Tailpipe emissions (CO, CO_2, NO_x and hydrocarbons) and fuel consumption as a function of time
Strengths: Unique abilities	**Weaknesses:** Hard to model future years; very specific purpose.

4.1.5 CORSIM

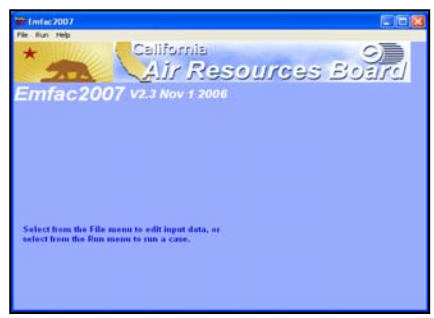
CORSIM was developed by the United States Federal Highway Administration (FHWA), a division of the Department of Transportation, as a microsimulation model designed for the analysis of freeways, urban streets, and corridors or networks. The tool includes two predecessor models, FRESIM and NETSIM.



Main inputs: Transport network topology and geometry; demand by mode; emissions rate by pollutant.	**Main outputs:** Transport network performance; emissions of CO, hydrocarbons and NO_x.
Strengths: high degree of precision in results.	**Weaknesses:** High price, limited number of vehicle classes

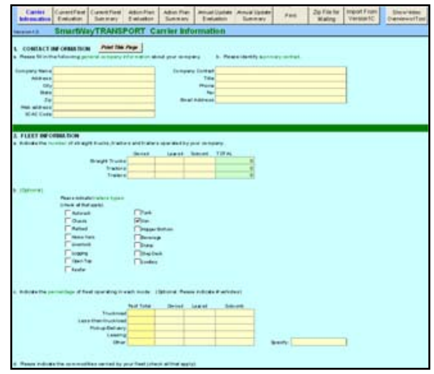
4.1.6 EMFAC

The California Environmental Protection Agency's Air Resources Board (ARB) created EMFAC, an emission inventory model that calculates emission inventories for motor vehicles operating on roads in California. This model reflects the ARB's current understanding of how vehicles travel and how much they pollute. The tool is a stand-alone application, and is available for free from the ARB's website (http://www.arb.ca.gov/msei/onroad/latest_version.htm).



Main inputs: Geographic area, vehicle class (choice of 13), calendar year and season, fuel, year of manufacture, annual vehicle miles, annual trips, inspection/maintenance information	**Main outputs:** Running exhaust emissions, starting emissions, hot soak emissions, diurnal loss emissions, resting loss emissions, estimated travel fractions and evaporative running loss emissions of hydrocarbons, CO, NO_x, CO_2, PM_{10}, $PM_{2.5}$, SO_x and Pb.
Strengths: Ease of use, high level of detail	**Weaknesses:** California-specific

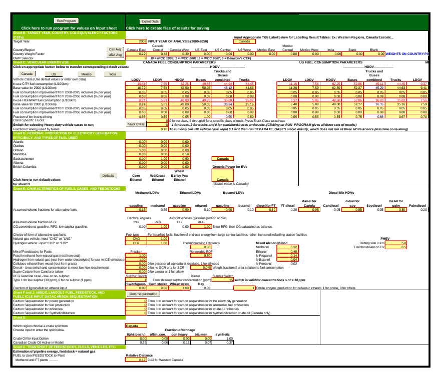
4.1.7 FREIGHT LOGISTICS ENVIRONMENT AND ENERGY TRACKING (FLEET) PERFORMANCE MODELS



FLEET was created by the US Environment Protection Agency to allow road-haulage companies to evaluate the effects of actions to save fuel and reduce emissions. The Excel-based tool can model a range of green strategies, including use of idling controls, aerodynamic upgrades, tire efficiency measures, weight reductions, lubricant changes, speed management strategies, and implementation of various emissions control technologies. The model is freely available from the EPA's website (http://www.epa.gov/smartway/transport/index.htm).

Main inputs: Current fleet characteristics (age, annual mileage, fuel consumption, idling information); existing and planned green strategies and technologies.	**Main outputs:** Potential savings in fuel, emissions (CO_2, NO_x and particulate matter) and money from full range of green strategies and those to be implemented.
Strengths: Only tool reviewed designed for road freight.	**Weaknesses:** Current model only goes up to 2003; unable to model changes in fuel mix.

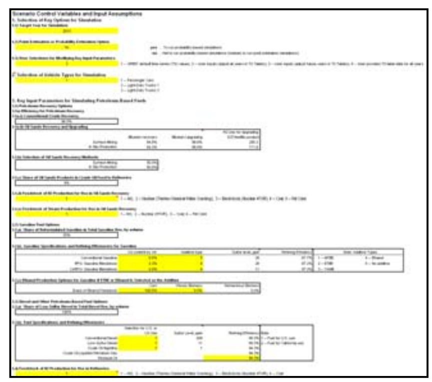
4.1.8 GHGENIUS



GHGenius was created by Natural Resources Canada to evaluate the lifecycle energy balances and emissions of existing and potential transportation fuels. It is implemented as an Excel workbook, and offers a huge amount of flexibility, but requires a large amount of set-up and inputs. The model is implemented in Microsoft Excel, and can be downloaded available for free from a dedicated website (http://www.ghgenius.ca/).

Main inputs: Vehicular energy use; regional production of electricity generation: types and efficiency of fuel used; characteristics of fuels, gases and feedstocks; fuel, feedstock, and fuel-cycle data; carbon sequestration; transport of feedstocks, fuels, vehicles, etc.; production of biomass; fertilizer manufacture, application; nutrient loss; land use; emissions displaced by co-products of fuel production processes; energy use and emissions at fuel stations; alternative fuel production.	**Main outputs:** CO_2-equivalent emissions per unit of energy delivered to end users, by stage and feedstock/fuel combination; total emissions over the whole upstream fuel-cycle, per unit of energy delivered to end users, by pollutant and feedstock/fuel combination; total emissions of all greenhouse gases; mass of emissions per GJ of fuel delivered to end users; CO_2-equivalent emissions, by vehicle/fuel and stage.
Strengths: Extremely comprehensive, captures all stages of fuel production	**Weaknesses:** Complexity and amount of input required

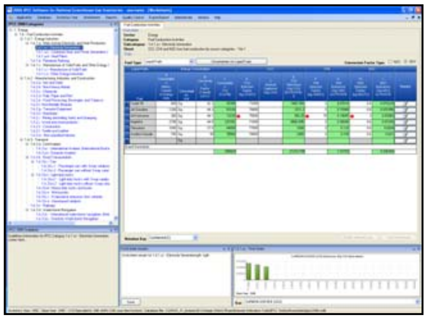
4.1.9 GREET (GREENHOUSE GASES, REGULATED EMISSIONS, AND ENERGY USE IN TRANSPORTATION)



GREET was developed by the Argonne National Laboratory (part of the US Department of Energy) to evaluate energy and emission impacts of a range of vehicle technologies and transportation fuels; the fuel cycle from wells to wheels; and the vehicle cycle through to material recovery and vehicle disposal. The model comes in two parts – GREET1 covers the well-to-wheels pathway, and GREET2 provides vehicle-cycle analysis. The two parts are independently implemented in Microsoft Excel, but a graphical user interface is available as an add-on programme to simplify scenario setup.

Main inputs: Vehicle and battery weight, vehicle component characteristics, vehicle lifetime, material composition of components, fuel economies, recycling information, material production characteristics.	**Main outputs:** Consumption of total energy and of fossil fuels (petroleum, natural gas, and coal) and emissions (CO_2, CH_4, N_2O, NO_x, VOC, CO, PM_{10}, $PM_{2.5}$, SO_x) from of well-to-pump, vehicle cycle and vehicle operation.
Strengths: Comprehensive in coverage; has very large range of fuel pathways	**Weaknesses:** Complexity and amount of input required

4.1.10 IPCC SOFTWARE FOR NATIONAL GREENHOUSE GAS INVENTORIES



The International Panel on Climate Change produced a comprehensive set of guidelines to evaluate a country or region's greenhouse gas emissions. The software is intended to provide a straightforward way to implement the guidelines. Currently, only fuel consumption activities (including transport), fugitive emissions from fuels and CO_2 transport and storage effects are included. The tool is a stand-alone piece of software, but may require the user to have Microsoft Excel installed. It can be downloaded for free from IPCC National Greenhouse Gas Inventories Programme's website (http://www.ipcc-nggip.iges.or.jp/support/support.html).

Main inputs: Consumption by energy industries, manufacturing, transport and construction; fugitive fuel emissions; CO_2 transport and storage; industrial processes and product use; agriculture, forestry and other land use; waste disposal methods.	**Main outputs:** Greenhouse gas emissions by year and source.
Strengths: The definitive calculator for greenhouse gas emissions.	**Weaknesses:** Works off consumption rather than causes (e.g. tons of fuel used rather than vehicle-km travelled)

4.1.11 MOBILE 6.2C

MOBILE was created by the USA's Environment Protection Agency (EPA), and is now on version 6.2. In its normal form, MOBILE calculates emission factors for 28 individual vehicle types in low- and high-altitude regions of the United States. MOBILE's emission factors estimates depend on various conditions, most of which can be adjusted from the default values. Many of the variables affecting vehicle emissions can be specified by the user. MOBILE can estimate emission factors up to calendar year 2050.

The tool was originally created for use in the USA, so Environment Canada commissioned an adaptation of the model to make it more suitable for use in Canada. The result of this was a set of province-specific tables of speed distribution by time of day, for use instead of the default values. Other input parameters are generally scenario-specific.

Main inputs: Year; month; daily temperature profile; altitude; fuel characteristics; humidity and solar load; annual mileage and age distribution by vehicle class; natural gas and diesel sales fractions; average speed distribution by hour and roadway; distribution of vehicle miles traveled by roadway type; hourly distributions of engine starts, engine start soak time distribution and trip ends;	**Main outputs:** Emissions of hydrocarbons, CO_2, CO, NO_x, SO_2, lead, NH_3, benzene, 2-methoxy-2-methylpropane (MBTE), methanal (formaldehyde), ethanal (acetaldehyde), 2-propenal (acrolein) and 1,3-Butadiene from start-up, running, hot soak (at trip end), resting (leaks and seepages), refuelling, brake wear and tire wear.
Strengths: Flexibility, range of emissions modelled.	**Weaknesses:** Not easy to use, large setup time

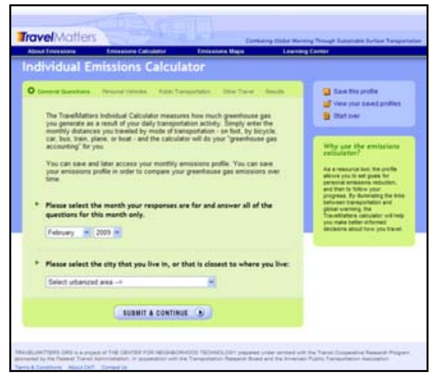
4.1.12 SATURN

SATURN (Simulation and Assignment of Traffic to Urban Road Networks) is a combined traffic simulation and assignment model developed at the Institute for Transport Studies, University of Leeds, UK, and commercially distributed by WS Atkins. SATURN is most suitable for the analysis of relatively minor network changes with potentially major impacts (such as the introduction of one-way streets, changes to junction controls, bus-only streets, etc.) and whose evaluation requires a detailed analysis of traffic behaviour at junctions. Modelled networks may range in size from 100 nodes (covering a larger neighbourhood) to thousands (covering several cities or a region). Emissions are calculated based on modelled vehicle speeds and travel distances.

Main inputs: Road network, demand by vehicle type and origin/destination.	**Main outputs:** Road usage statistics (including travel times and route choices); CO_2, NO_x, SO_x, PM_{10}, fuel consumption.
Strengths: High precision	**Weaknesses:** Complexity of set-up and calibration.

4.1.13 TRAVELMATTERS: INDIVIDUAL EMISSIONS CALCULATOR

TravelMatters is a website providing information about the impacts of personal transportation on greenhouse gas emissions. One of the online tools it offers is an individual emissions calculator, designed to convert a person's mileage for all modes of transport into CO_2 emissions levels. The tool is free to use, and is web-based (http://www.travelmatters.org/calculator/individual/).



Main inputs: Monthly mileage by foot, bicycle, car (split by make(s)/model(s) travelled), bus, train, plane (including number of take-offs) and boat; user's home city.	**Main outputs:** CO_2 emissions
Strengths: Ease of use.	**Weaknesses:** USA-specific.

4.1.14 TRAVELMATTERS: TRANSIT PLANNING CALCULATOR

As mentioned before, TravelMatters is a website providing information about the impacts of personal transportation on greenhouse gas emissions. One of the online tools it offers is a transit agency emission calculator. The effects of various potential upgrades (such as changing fuels or vehicle types) can be modelled. The tool uses the Mobile 6.2 model to perform its calculations, using data that is either specific to the chosen area, while the last three values are the most likely values for the agency.

Main inputs: Transit agency, fleet mix, fuels, electricity generation sources, climate data.	**Main outputs:** Emissions of CO_2, CO, VOC, NO_x, $PM_{2.5}$.
Strengths: Ease of use.	**Weaknesses:** Only models transit agencies in the USA.

4.1.15 URBAN TRANSPORT EMISSIONS CALCULATOR (UTEC)

The urban transport emission calculator (UTEC) was created by IBI for Transport Canada. It was originally created as an Excel workbook, but has also been implemented as a webpage (http://wwwapps.tc.gc.ca/Prog/2/UTEC-CETU/Calculator.aspx). The tool takes vehicle-km (for personal and commercial vehicles) and passenger-km (for transit), and combines them with province-level emission factors, and produces data on a wide range of emission types. The tool permits variations in fleet technology breakdown for personal vehicles, commercial vehicles and buses. Transit emissions can also take account of different passenger rail modes. Possible scenario years vary from 2006 to 2031 at five-year intervals.

Main inputs: Vehicle-km for personal vehicles, commercial vehicles and buses; passenger-km for railed transit.	**Main outputs:** CO_2e emissions (upstream and in operation) by vehicle type; CO, NO_x, SO_2, VOC, TPM, PM_{10} and $PM_{2.5}$ emissions by vehicle type.
Strengths: Ease of use, province-specific, able to model different fuel mixes.	**Weaknesses:** Only two road types (city and highway); cannot choose arbitrary future year.

4.1.16 VISSIM

VISSIM is a microsimulation model developed by software company PTV AG to model urban traffic and public transit operations. The stand-alone program can analyze traffic and transit operations under various constraints, and is used to evaluate the various alternatives based on transportation engineering and planning measures of effectiveness. Vehicle emissions can be calculated with the aid of optional add-in module.

Main inputs: Transport network topology and geometry; demand by mode; emissions characteristics by mode/vehicle type.	**Main outputs:** Transport network performance; emissions by vehicle type, of benzene, CO, CO_2, hydrocarbons, NO_x, TPM, SO_2 and soot.
Strengths: high degree of precision in results; user able to specify emissions profile.	**Weaknesses:** High price, large amount of set-up required.