PUBLIC TRANSIT PROJECTS GHG QUANTIFICATION GUIDE

SUBMITTED TO:

CLIMATE CHANGE CENTRAL

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Environmental Strategies. Business Solutions.

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1.0 INTRODUCTION

Introductory note to be provided by Alberta Transport.

1.1 OVERVIEW OF THE GUIDE

This guide is intended to provide Alberta transit system operators and other project proponents with the basic tools necessary to accurately and credibly calculate the greenhouse gas (GHG) emissions and potential emission reductions of transit projects that they may implement. Approaches presented herein draw heavily on accepted industry best practices and standards, which have been expressed in a way that is tailored to the needs of project proponents while remaining generic enough to apply to a broad range of transit project types.

The guide begins with introductory sections that provide a brief background on greenhouse gases, when you would want to quantify them, and standard ways of doing so. The guide then moves to more transit-focused sections, culminating in the presentation of a step-wise approach to calculating GHG emissions and emission reductions tailored to transit projects in Section 6.0. Finally, appendices are included which provide standard emission factors and assumptions, more detail on specific methodologies, and other supporting information that may be useful for a project proponent.

1.2 WHAT IS A GREENHOUSE GAS?

Certain atmospheric gases have the ability to trap energy within the earth's atmosphere when solar energy is reflected off of or otherwise radiated by the earth. These gases, called greenhouse gases (GHGs) due to their namesake's ability to retain heat, take many forms and result from both natural and man-made (anthropogenic) processes. While these gases play a central role in earth maintaining a climate warm enough for life, recent increases in the rate of anthropogenic emissions of GHGs are generally recognized as contributing to an overall warming of the climate.

Most GHGs fall into one of six categories noted below:

Type	Typical Emission Sources
Carbon dioxide (CO_2)	Fuel combustion (carbon-based fuels such as fossil fuels)
Methane (CH_4)	Fuel combustion (due to incomplete combustion of carbon-based fuels); anaerobic degradation (landfill gas)
Nitrous Oxide (N_2O)	Fuel combustion in a nitrogen atmosphere (e.g. ambient air)
Hydrofluorocarbons (HFCs)	Leaking cooling systems (HFCs are typically used as refrigerants)
Perfluorocarbons (PFCs)	Aluminum production; specialty applications
Sulfur Hexafluoride (SF_6)	Leaking electrical transformers / switch-gear (SF_6 is used as an insulator in these devices)

Of these six gases, the first three, CO_2, CH_4, and N_2O are the most common and tend to be released as a result of chemical processes such as fuel combustion and breakdown of organic wastes under anaerobic (de-oxygenated) conditions (e.g. in landfills, waste water treatment, etc.).

All GHGs are not, however, created equal. Because each has a different molecular structure and it is this structure that affects the ability to absorb energy, some GHGs are more potent than others. Additionally, molecular structure also influences how long a molecule of a particular compound remains in the atmosphere before being transferred to other media (e.g. absorbed by plants, the ocean, soils, etc.) or destroyed.

The potency of different GHGs is typically expressed in terms of an equivalent amount of CO_2 (carbon dioxide equivalent, or CO_2e) over a 100-year period, and is referred to as a GHG's 100-year global warming potential (GWP). For instance, methane is currently considered to be 25 times more potent than CO_2 (GWP = 25), and nitrous oxide is considered to be 298 times more potent that CO_2 (GWP = 298)[1]. Other GHGs can be many thousands of times more potent than CO_2. The GWP of CO2 is 1.

1.3 OVERVIEW OF GHGS IN THE TRANSPORTATION SECTOR

In the transportation sector, tailpipe emissions are the main source of GHGs, due to combustion of vehicle fossil fuels, including gasoline and diesel. Additionally, "upstream" emissions related to production of those vehicle fuels, as well as generation of grid electricity for electric vehicles, are also important, though lesser, contributors to overall emissions[2]. In the case of public transit systems, emissions are also associated with operating transit infrastructure, such as providing power and heat to terminals, stations, and other buildings and equipment.

The greenhouse gases released from transit vehicles are primarily in the form of carbon dioxide (CO_2), but smaller levels of methane (CH_4) and nitrous oxide (N_2O) also are emitted depending on the fuel and engine technology used.[3]

Of course, while public transit activities result in GHG emissions, the alternative – use of cars and trucks – generally emits significantly greater quantities of GHGs per passenger transported. Thus, sustainable transit initiatives can reduce vehicle transportation emissions through increasing the efficiency of existing fleets, and by reducing the number of less efficient cars and trucks on our roads through increasing transit ridership.

For more details on transport sector GHG emission sources, please see Section 4.0.

2.0 WHO MONITORS, CALCULATES, AND REPORTS ON GHG EMISSIONS?

GHG monitoring, accounting and reporting can occur at many levels. Regardless of the level of reporting, it is always important to consider the intended audience for the GHG emission calculations and results as this will have an impact on the associated level of effort required. For instance, emission reduction estimates for an internal corporate audience might not need to be prepared at the level of accuracy required for applying for external project funding or for generating tradable emission reduction credits that could be sold to other companies.

With that in mind, three common levels of GHG reporting are described below.

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[1] Intergovernmental Panel on Climate Change, 2007. Fourth Assessment Report. Available at http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_Ch02.pdf

[2] Transport Canada. News Item No. H145/06 November 14, 2006. http://news.gc.ca/web/view/en/index.jsp?articleid=255709&keyword=Investment&&page=84, accessed October 6, 2008.

[3] EPA (August 2008). *CLIMATE LEADERS GREENHOUSE GAS INVENTORY PROTOCOL OFFSET PROJECT METHODOLOGY for Project Type: Transit Bus Efficiency*. http://www.epa.gov/stateply/documents/resources/transit_protocol.pdf, accessed October 9, 2008.

National-Level

At the national level, Canada has a legal obligation to submit an inventory of its GHG emissions to the United Nations Framework Convention on Climate Change (UNFCCC) on an annual basis. Detailed GHG emissions data at national, provincial, and sectoral levels are submitted to the UNFCCC in Canada's National Inventory Report (NIR)[4]. The report also includes an analysis of emission trends, factors affecting those trends, and detailed descriptions of the methods, models and procedures used to develop and verify the data.

The data assembled in the NIR represents a "top-down" approach to emissions monitoring and reporting, which means that it is generated using high-level economy-wide modeling of emissions based on a sample of relevant data across Canada versus by summing up emissions from each and every emitting entity / facility (which would be "bottom-up").

The responsibility for preparing this report falls under the mandate of Environment Canada, and is done in consultation with a range of stakeholders.

Facility / Organizational-Level

Facilities emitting the equivalent of 100,000 tonnes (100kt) or more of greenhouse gases (in CO2 equivalent units) per year are required to submit an annual report as part of Environment Canada's GHG Emissions Reporting program. This is legislated under the Canadian Environmental Protection Act, 1999 (CEPA 1999). The Province of Alberta also has emission reporting requirements as part of it's Specified Gas Emitters Regulation. Other facilities or organizations may also choose to calculate their emissions, referred to as an emissions inventory, for various purposes.

Data for facility / organizational reporting is typically gathered using a detailed bottom-up approach, and is usually compared against emissions from a previous year (i.e. the "base year") to assess progress over time. Organizations conduct a detailed analysis of their emission sources, and estimate emissions based on measured parameters.

This guide is targeted at assisting project proponents with quantifying emissions for transit GHG projects.

Projects

Public or private organizations may also monitor, account and report on their GHG emissions at the project level. GHG projects are specific undertakings designed to achieve emission reductions, and reporting for projects differs from the total inventory approach described above for the facilities case. The aim of monitoring, accounting and reporting here is to zero in on what the emissions would have been had the project not been implemented, which involves comparison against a hypothetical "baseline" case that never actually happens (because the project is implemented) instead of comparing against emissions from a previous year. It is also not necessary to consider total emissions in this case (unlike the facility / organizational-level approach described previously) – instead, focus is placed on activities with emissions that change between the project and baseline case.

Project monitoring, accounting, and reporting may be done for a variety of reasons, such as to quantify a project's emissions benefits as a requirement for obtaining funding; to quantify emissions reductions to sell as a carbon offset in a carbon market.

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[4] Environment Canada website. Canada's GHG Inventory. http://www.ec.gc.ca/pdb/ghg/inventory_e.cfm, accessed October 24, 2008.

3.0 HOW TO CALCULATE PROJECT-BASED GHG EMISSIONS

A considerable amount of general GHG quantification guidance is now available to help guide transit system operators and other project proponents engaged in GHG emission reduction projects. Highlights from current best practices and standards are noted below, and should be kept in mind when employing the transit-focused approaches documented in Section 6.0.

3.1 USE ACCEPTED GHG QUANTIFICATION APPROACHES

A number of different approaches, described below, are commonly used to quantify GHG emissions for a particular emission source.[5]

Monitoring and direct measurement

This type of method uses equipment to directly measure quantities of pollutant emitted as a result of an activity. This may involve continuous emission monitoring systems (CEMS) (where emissions are recorded over an extended and uninterrupted period), predictive emission monitoring (correlates measured emission rates to process parameters) or source testing (e.g. stack sampling). This method is the simplest from a calculation perspective and generally most accurate, as quantities of GHGs are directly assessed; however, it typically requires costly monitoring equipment and analysis that is only necessary in specific cases.

Mass balance

This type of method applies the law of conservation of mass to a facility, process or piece of equipment. The accumulation and depletion of a substance is considered when taking the difference in the input and output of a unit of operation to determine emissions. For example, the amount of carbon input in a fuel minus carbon in solid wastes (e.g. ash) from fuel combustion would give the amount of carbon released to the atmosphere during combustion.

The use of standard emission factors is the most common way of quantifying emissions.

Engineering estimates

Engineering estimates may involve estimating emissions from engineering principles and judgment, knowledge and understanding of the physical and chemical processes and laws involved, as well as the design features of the source.

Emission factors

This method uses standard emission factors (EFs) to estimate the rate at which a pollutant is released into the atmosphere (or captured) due to a process activity or unit throughput, and is the most common quantification approach.

An emission factor is the average emission rate of a given GHG for a given source, relative to units of activity. As such, an emission factor is expressed as the ratio of the amount of GHG emission, typically expressed in mass units such as kg CO2e, per level of a given activity, where the activity could be liters of fuel consumed, km driver, hours operated, or any other metric relevant to a particular process or emission source. A particular emission factor would initially be developed based on one of the other methods listed

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[5] Environment Canada website. Estimate methods. http://www.ec.gc.ca/pdb/GHG/guidance/calcu_e.cfm, accessed October 24, 2008.

in this section, but would then be made available for use by others, for instance in government, industry, or in scientific or other publications. They are usually obtained by taking the average of all available data of acceptable quality, are generally assumed to represent long-term averages, and as such are used to estimate future emissions.[6]

The general equation for emissions estimation using this methodology is:

Equation 1: $\text{Emission}_{\text{pollutant}} = \text{Activity Level}_{\text{process}} * \text{Emission Factor}_{\text{pollutant}}$

3.2 COMPARE YOUR PROJECT TO A BASELINE

As described in section 2.0 above, evaluating the GHG benefits of a project involves quantifying the emissions and emissions reductions that occur directly as a result of implementing the project.

One of the most fundamental concepts with respect to project-based emission quantification is that if a project generates emission reductions, then project emissions must be reduced relative to something else – i.e. a reference benchmark (or "baseline"). The baseline represents the hypothetical case of what would have happened in the absence of the project. For instance, in the absence of the project, we would have … continued to operate the old buses; purchased new industry standard buses (versus the more advanced project buses); etc.

To successfully evaluate the GHG benefits of a project, a systematic analysis of the changes in emissions resulting from the project over the baseline case is undertaken in order to understand and quantify their GHG impacts.

This relationship is described in the following equation:

Equation 2: $\text{GHG reductions} = \text{GHG emissions}_{\text{project}} - \text{GHG emissions}_{\text{baseline}}$

Emission reductions from a project are obtained by comparing project emissions to emissions from a baseline scenario.

Where project emissions are less than baseline emissions, a negative value will result from applying Equation 2, representing the net decrease in emissions due to the project. Note that subtracting baseline from project emissions focuses the calculation on only those emissions that change directly as a result of the project activities, such as changes to the types of buses used, modes of travel (e.g. shifting from cars to light rail), etc.

In identifying the baseline, it is important to consider the services provided by the project (e.g. moving passengers, heating a building, manufacturing a particular product, etc.) and ensure that the baseline provides equivalent types and levels of service (otherwise it is not a fair comparison).

3.3 ADHERE TO QUANTIFICATION STANDARDS

As concern regarding GHG emissions and climate change has increased over the years, effort has been directed at developing standardized ways of calculating GHG emissions that allow for accurate comparisons between different projects, companies, organizations and countries. Most standardized approaches, including the internationally recognized ISO 14064 series of standards and the WRI/WBCSD[7] GHG Protocol, include a consistent set of steps and requirements for developing a GHG

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[6] EPA, Technology Transfer Network Clearinghouse for Inventories & Emissions Factors website. *Emissions Factors & AP 42*. http://www.epa.gov/ttn/chief/ap42/, accessed October 24, 2008.

[7] World Resource Institute / World Business Council for Sustainable Development

project quantification report. The methodology provided in section 6.0 is consistent with approaches outlined in quantification standards.

3.4 FOLLOW QUANTIFICATION PRINCIPLES

To enhance the credibility and usefulness of GHG project quantifications, it is recommended that the following principles, common to most GHG quantification standards such as ISO 14064 and the WRI GHG Protocol, are adhered to regardless of the methodology chosen.

- Relevance: your quantification should be prepared considering the needs of the intended audience for or user of the results (note: the intended user needs to be determined by the project developer).
- Completeness: Attempts should be made to thoroughly consider all relevant sources of GHG emissions, and all supporting information should be transparently documented.
- Consistency: This is required in order to ensure meaningful comparison of GHG-related information. In particular, like emissions need to be compared in baseline and project scenarios using consistent approaches, and where a project developer undertakes multiple projects, resulting emissions should be calculated using consistent approaches to facilitate comparisons.

Consistent System of Measurement

One specific aspect of consistency bears further mention. Project developers should be especially diligent in ensuring that a consistent measurement system (metric is recommended, or alternatively imperial) is used for all calculations. Inadvertent use of both types of systems simultaneously in calculations is a classic source of error that can occur in projects big and small.

- Accuracy: you should strive to prepare emission quantifications that are as accurate as possible and with minimum uncertainty, considering the intended uses of and audiences for the results.
- Conservativeness: When in doubt, make choices, assumptions, etc. that under-estimate rather than over-estimate emission reductions.
- Transparency: clearly document your calculations, assumptions and decisions in a clear, upfront manner that facilitates review by interested parties, auditors, etc.

For more insight into these principles and how to apply them, please see Annex A of ISO 14064-2.

3.5 REFERENCE RELIABLE DATA SOURCES

As one might expect, the most reliable data for project calculations is data taken directly (i.e. monitored) from the project vehicles, equipment, buildings, etc. However, in many cases it is necessary to also rely on other data sources where it is too costly or impractical to determine project-specific values through direct monitoring. For instance, while it should be relatively straightforward to monitor fuel consumption for project vehicles, it is unlikely that a project proponent would conduct tail pipe emissions tests on project vehicles to determine precisely how many GHGs are emitted per amount of fuel used.

Thankfully, there are many available reference data sources, some of which are identified in Appendix 4. In identifying appropriate sources for data or other assumptions, the following should be considered (building on requirements provided in ISO 14064-2 regarding good practice guidance):

i. **Are the data from a recognized source?**

Recognized sources of data and assumptions typically have been subject to some form of independent peer review, and are generally recognized as authoritative sources for data and assumptions. In the GHG context, examples include, but are not limited to:

- Government publications, such as Canada's national GHG inventory, Statistics Canada publications, provincial and municipal transport studies, etc.
- Approved GHG quantification protocols, such as those in Alberta and other Canadian systems as they are developed, international protocols as part of the Kyoto Protocol's Clean Development Mechanism, etc.
- Scientific journals and other publications, which are typically peer-reviewed prior to publication
- Industry experts with relevant qualifications and experience

ii. Are the data relevant to the project conditions?

Likely the subject matter of a particular data source being considered will be relevant to the task at hand - otherwise it would not be evaluated in the first place. However, attention should be paid to the specific conditions or circumstances under which the data should and should not be applied. For instance, factors developed based on conditions other than those of the project, such as climatic, demographic, infrastructure development, etc. may not be suitable for a project being undertaken in Alberta. For instance, taking a vehicle fuel efficiency factor from a jurisdiction with year-round moderate temperatures may result in under-estimates of fuel use when used in a jurisdiction with cold winter-time temperatures.

iii. Are the data current?

More recent data would usually be preferred over older sources. However, "current" is a subjective term. To help determine what "current" should mean for a particular project, consider the following:

- *Would the value be expected to change over time, and if so, how quickly would it change?* If a particular type of data was expected to change every year, 5 year old data would likely not be considered current.
- *Is the science regarding the determination of the data improving, and if so, how quickly?* If there is solid understanding regarding a particular value that is not expected to change over time, data that is 5 or 10 years old might still be considered current. For instance, CO2 emissions per liter of diesel fuel combusted is a well-known quantity, so data that is a few years old is likely the same as the most recent data. However, in the case of global warming potentials, the science continues to evolve every couple of years, periodically resulting in more accurate numbers.

A Note on Data Availability:

Depending on the project's budget, it will often be necessary to use some data that are less recognized, relevant, and/or current than ideal – this is unavoidable, particularly since a project proponent is usually focused on implementing a transit project and not on preparing a highly rigorous GHG calculation! In such circumstances, the following should be considered:

- Can the available data be adjusted in some simple way to make them more representative of project conditions, while considering the conservativeness principle described above? For instance, perhaps emissions could be increased by 10% to account for expected increases in fuel consumption due to a colder climate.
- Be sure to transparently acknowledge where less than ideal data are being used, and clearly document any adjustments that are made to the data to better fit project circumstances.

4.0 TYPICAL TRANSIT EMISSION SOURCES

The main function of any public transit system is the physical transporting of passengers between destinations. A transit system's direct and related emission sources will emerge from the activities that allow this primary function to be successfully executed. Figure 1, below, captures common emission sources applicable to all transit project types that would occur on an on-going basis as a transit system operates. These sources include both emission sources directly related to transit system operations, such as vehicle use, as well as emission sources related to transit system operation, such as generation of electricity or production of fossil fuels at remote locations not controlled by a transit system operator but that are nonetheless essential for operation of the system.

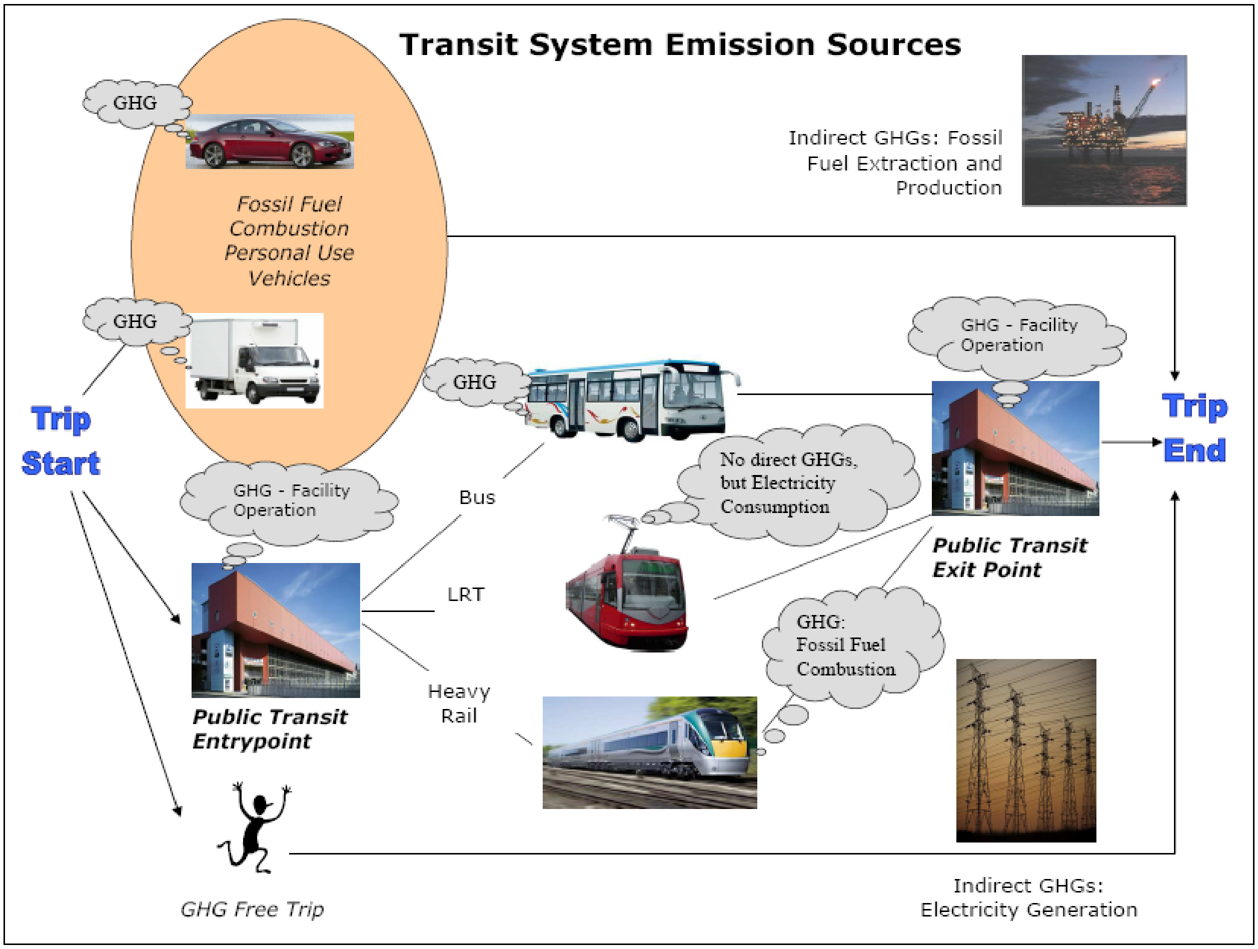

Figure 1: Potential Transit System Emission Sources

In addition to emission sources pictured here, other potentially relevant, though typically less significant, emission sources would include those related to manufacturing vehicles, building infrastructure, decommissioning equipment, and other similar activities that happen only once versus on an on-going basis. Please note that this list of on-going and one-time emission sources is not intended to be exhaustive, but rather to serve as a starting point for fully identifying emission sources that are potentially relevant to a transit project.

To assist with identifying emission sources for your project, common emission sources are described below. These emission sources have been categorized based on their typical magnitude relative to other emission sources, though these categorizations should only be used as a rule of thumb, and would ideally be re-evaluated based on project-specific circumstances. For approaches to calculating associated emissions, please see Section 6.6.

4.1 PRIMARY TRANSIT EMISSION SOURCES

The primary emission sources described below all involve the conversion of primary energy sources (typically carbon-intensive fossil fuels) to secondary forms of energy (e.g. heat, electricity, mechanical energy) used in transit vehicles and facilities. These emission sources are also all linked to direct provision of transit services – namely the transport of passengers from one point to another.

Vehicle Fuel Combustion

This emission source results from the combustion of fuels during operation of vehicles in various capacities including:

- Combustion of fuel during transport of passengers
- Combustion of fuel while idling
- Combustion of fuel while driving with an empty vehicle, where such driving is a direct result / requirement of transporting passengers (e.g. moving to and from a garage, to and from maintenance facilities, etc.)

These “tailpipe” emissions are the main source of transit project GHGs given the carbon-intensive nature of most vehicle fuels, namely fossil fuels such as gasoline and diesel. Emissions from fuel combustion are quantified through applying an appropriate emission factor to quantities of fuel combusted. The emission factor translates quantities of fuel combusted into amounts of CO_2e emitted through the combustion process. Different emission factors exist for different fuel types, and for different vehicle categories (e.g. light duty passenger vehicle, public transit buses etc.).

In the project case, emissions from transit vehicles need to be considered.

In the baseline case, emissions from vehicles that would have been used in the absence of the new transit project need to be considered. Vehicles to be considered include cars, trucks, and potentially existing transit vehicles.

Grid Electricity Generation for Electric Vehicles

This emission source results from activities requiring electricity consumption in vehicles. Electric vehicles do not directly emit GHGs, however the generation of electricity required to power them does.

The amount of GHGs emitted to generate the electricity required depends on how the electricity is generated. For example, coal plants produce higher levels of GHGs than do hydro projects. Power generated through wind, solar or other green technologies produces virtually no GHGs.

For transit projects in Alberta, it is recommended that standard, provincially accepted grid emission factors be used to convert electricity consumed into GHGs. Two potential approaches include using the average emissions intensity of existing grid-connected generators (as published in Canada’s GHG Inventory, 2006 value for Alberta) and using a more conservative factor determined by considering both existing and potential new generators (e.g. current value: 0.65 tonnes CO_2e/MWh). An exception here would be projects that derive their power from green sources.

Transit Facility Operation

This relates to all activities associated with the operation of buildings, facilities, or any other infrastructure involved in a transit system (e.g. park and ride terminals, bus stations, offices).

- The operation of transit facilities result in GHG emissions through:
- On-site combustion of fuels for heat, steam, operation of electrical generators, etc.
- On-site combustion of fuels to operate equipment
- Off-site generation of grid electricity used in a facility for heat, cooling, lights, mechanical systems, equipment, etc.

Methodologies to quantify GHGs are the same as for fuel combustion and electricity generation in the vehicle case, though different emission factors may apply.

4.2 SECONDARY TRANSIT EMISSION SOURCES

The following secondary emission sources tend to be smaller in magnitude than primary sources, and are associated with supporting activities versus activities that directly provide primary transit services. With the exception of fuel extraction and production, for most transit projects, these emission sources could be excluded from consideration without having a major impact on the overall accuracy of emission reduction calculations. However, to enhance accuracy and credibility of emission reduction calculations, this assumption should be re-evaluated based on project-specific details.

Fuel Extraction and Production

This emission source includes all activities associated with the extraction and production / refining of fossil fuels or other feedstocks (such as biomass in the case of biodiesel blends) that are subsequently combusted in transit vehicles or used to heat/cool transit facilities. Because fuel extraction and production is itself an energy-intensive activity that typically consumes significant quantities of fossil fuels, and since the amount of fuel required is directly linked to on-going provision of primary transit services, this is the one secondary transit emission source that tends to be relatively significant – it would not be surprising for these emissions to represent 15% or more of emission associated with combusting the produced fuels. As a result, these emissions are often quantified as part of transit emission reduction projects.

As with generation of grid electricity, emissions resulting from fuel extraction and production are referred to as indirect, upstream emissions. Indirect, upstream emissions are generated from an activity that is required as an input to the project, but are not directly controlled by the transit system operator.

Emissions from fuel extraction and production are calculated through the application of an emission factor to quantities of fuel consumed in the transit system.

Fuel Transportation

This emission source is due to the transport of fuel from a production facility to the end use location. Transportation can involve various modes, including truck (e.g. gas, diesel, propane) and pipeline (e.g. natural gas, crude oil prior to refining).

This emission source is another example of an upstream, indirect emission. Emissions produced from fuel transportation could be calculated through the application of an emission factor to quantities of fuel consumed.

However, because transport distances are likely similar for project and baseline and the project would typically see a decrease in fuel consumption and related transport, excluding it will underestimate project benefits a little bit and is thus conservative. These emissions are also usually small compared to other sources, so their exclusion should not have a significant impact on overall emission reductions.

Vehicle maintenance

This includes all activities associated with maintaining vehicles in operational condition. These activities include:

- Routine maintenance
- Minor repairs
- Fluid, filter and minor component replacement
- Major repairs / overhauls

These activities would not typically represent a significant emission source. Additionally, where transit vehicle maintenance were to increase due to increased ridership, one would expect a corresponding decrease in maintenance required for cars, trucks or other vehicles that are used less often.

Transit Facility Construction

This includes all activities associated with the construction of transit facilities (such as transit terminals) that would be required in order to facilitate an increase in passenger transport due to a new transit project.

Emissions resulting from transit facility construction are most likely negligible over a transit project's lifetime when compared to key fossil fuel combustion emission sources. As such the exclusion of this emission source from most quantification projects is likely justified. However, this element may be included if it is felt to be significant and relevant quantification data is available.

Facility and Vehicle Decommissioning

This includes all activities associated with the end-of-life decommissioning, recycling and disposal of facilities and equipment (such as transit facilities, buses, rail cars, etc.) that would be required in order to facilitate an increase in rail transport due to the project.

Emissions resulting from facility and vehicle decommissioning are most likely negligible over a transit project's lifetime, and little difference between project and baseline cases would be expected. As such the exclusion of this emission source from most quantification projects is likely justified.

Transport Infrastructure Construction

This includes all activities associated with building new roads, rail track, bridges, and related infrastructure necessary for passenger transportation.

While such activities can involve significant energy use and associated emissions, particularly for larger capital projects, when contrasted with emissions that transit projects might also avoid, such as those associated with constructing new highways, etc. these emission are often excluded from consideration. When such emissions are spread over the lifetime of the infrastructure, their significance is reduced further.

For larger capital projects, project proponents may wish to estimate associated emissions by focusing on production of key types of materials required (e.g. concrete, steel, asphalt) and expected operation and associated fuel use of construction equipment.

Transport infrastructure maintenance

This includes all activities associated with periodic maintenance of road and transit infrastructure necessary for passenger transportation. This would include routine maintenance as well as major overhaul / replacement of key infrastructure components (e.g. track, bridges, road surfaces, etc.).

This would not be expected to be a significant emission source, particularly since one would expect that increases in maintenance due to increased public transit use would be offset by reduced maintenance due to personal vehicle use.

5.0 SCOPE AND APPROACH OF THE GUIDE

5.1 SCOPE AND APPLICABILITY

This guide provides a generalized approach to calculating the GHG emission reductions that occur from a wide variety of transit projects. While data gathering and monitoring is likely easiest when limited to only one transit system or jurisdiction, the guide may nevertheless be applied to transit projects that span multiple jurisdictions, such as enhanced/new service between cities.

The main activity in any public transit system is the movement of passengers between locations using transit vehicles. It then follows that the primary elements to consider in transit projects which aim to reduce GHG emissions are either the transit vehicles used, and/or the number of passengers served. Generally speaking, transit GHG reduction projects will fall into one or both of the following two categories: efficiency projects and modal shift projects.

*This guide is targeted to transit operators seeking to quantify their emissions at the **project** level.*

5.1.1 EFFICIENCY PROJECTS

Efficiency projects are solely based on improvements to transit vehicle or facility efficiency in terms of GHG emissions per level of service provided, and as such result in GHG reductions irrespective of changes in transit ridership levels.

Vehicle Efficiency Projects

In the case of vehicle improvements, GHG reductions occur through the introduction of one or more transit vehicles utilizing a lower carbon content fuel or operating with improved fuel economy in comparison to the transit vehicles that would have operated in absence of the project vehicles. Examples of potential projects include, but are not limited to:

- Upgrading existing vehicles with more efficient fuel consumption technologies;
- Purchase of new transit vehicles to replace existing transit vehicles of the same type (e.g. bus, train, etc.); and
- Adjustment of operating practices resulting in reduced fuel consumption without changing the vehicles themselves

Some features that would create improvements in fuel-efficiency include:

- Multi-valve engines, lean burn engine technology, improved transmissions, and new lightweight, high-strength materials (all available fuel technologies that could help make the average vehicle meet increased fuel efficiency levels);[8]

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[8] Hornung, R. (1998) *Canadian Solutions: Practical and Affordable Steps to Fight Climate Change*. http://www.pembina.org/pub/8, accessed October 2008.

- reduction in vehicle and/or engine size; reduction of energy consumption by design considering reduction of drag, improved tire pressure, etc., and
- Use of hybrid power trains.

Transit Facility Efficiency Projects

In the case of transit facility efficiency projects, GHG reductions occur through improving the energy efficiency of various building systems and sources of energy demand, including building heating and cooling systems and other equipment. Potential projects include, but are not limited to:

- Replacement of aging furnaces with high-efficiency furnaces
- Switching to green electricity alternatives (e.g. use of solar panels, purchasing electricity from green services providers etc.).

A pictorial representation of a sample efficiency project is provided in the diagram below.

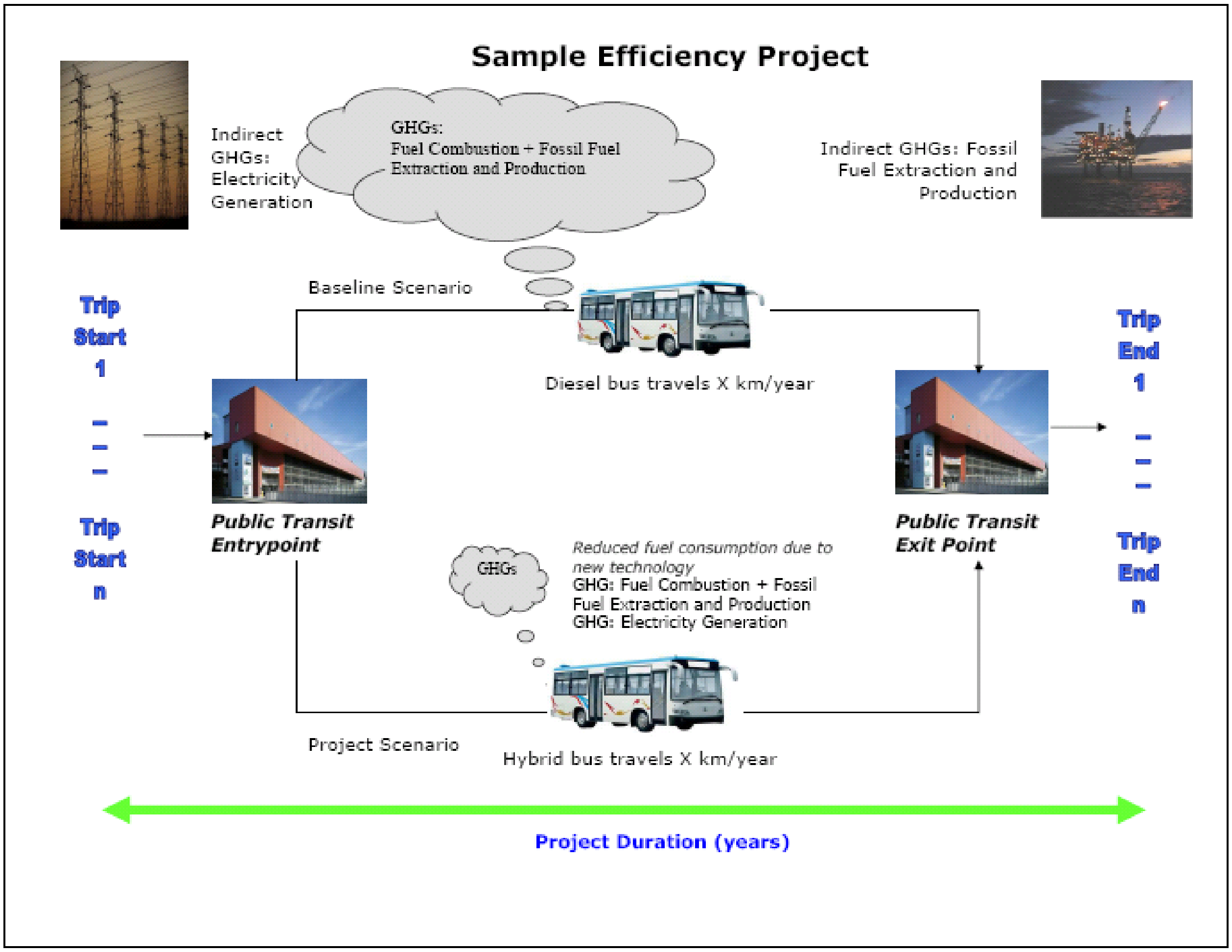

Figure 2: Illustration of Sample Efficiency Project

5.1.2 MODAL SHIFT PROJECTS

Modal shift projects result in emission reductions due to shifting passengers from more to less emissions-intensive forms of transportation (such as from cars to buses, or from buses to cleaner transit alternatives). Potential transit modal shift projects could include:

- Programs to increase ridership on existing transit fleets (e.g. divert car use to existing transit services
- Transfer of ridership to new transit services (e.g. from cars / buses onto a new commuter rail line)
- The construction of transit facilities that encourage modal shift, such as the construction of new park and ride and regional transit terminals.
- New transit systems that provide enhanced service to regional communities and reduce commuter traffic; and
- Light Rail Transit (LRT) and inter-city commuter rail systems or system extensions.

Fundamentally, modal shift projects can be distilled into one of the following scenarios:

- Increased transit ridership on existing transit modes
- Existing transit ridership on new transit modes
- Increased transit ridership on new transit modes

Programs that result in emission reductions due to improved technologies on the same vehicle type (e.g. replacing old technology buses with new technology buses) are considered in the Efficiency Project Type section above.

A pictoral representation of a modal shift project is provided in the diagram below.

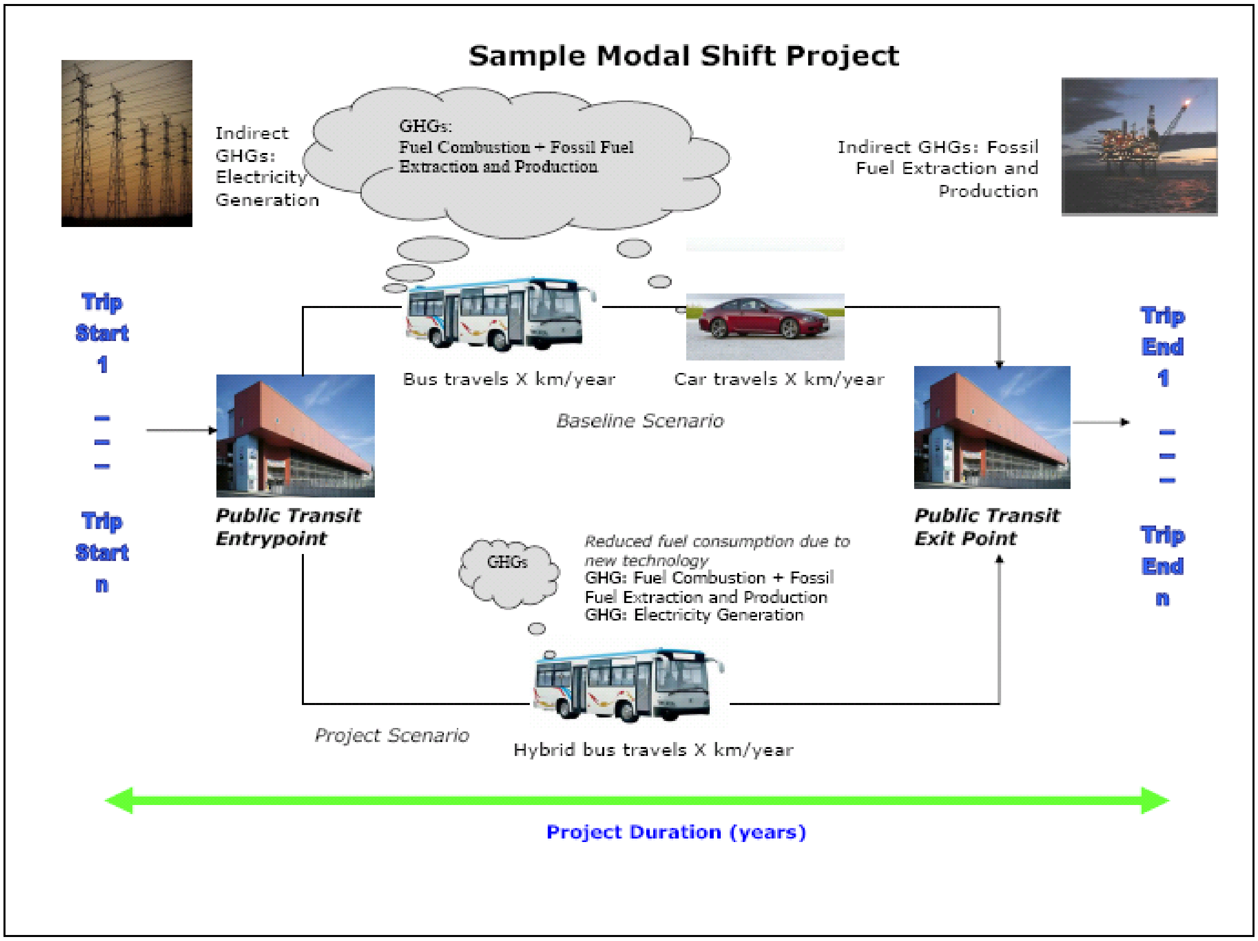

Figure 3: Illustration of Sample Modal Shift Project

5.1.3 OTHER PROJECT TYPES

Other transit projects can also offer GHG and other benefits; however, they are not discussed within the scope of this guide. For instance, “enabling” projects such as strategic land acquisitions that do not result in immediate benefits but that set the stage for future GHG reduction initiatives would have benefits in the long-run, but those future benefits would not be quantified using the approaches presented in this guide.

Detailed GHG quantification approaches for energy efficiency and modal shift projects are provided in Section 4.0.

5.2 QUANTIFICATION APPROACH

Emissions for transit projects can in theory be determined using any of the approaches outlined in section 3.1. For example, it is possible to directly measure levels of CO_2 emitted from the tailpipes of transit vehicles, however obtaining data using such an approach for an entire fleet is both expensive and impractical. It is also virtually impossible to do so for vehicles that need to be included in emissions quantifications, but that are not part of a transit fleet controlled by the transit operator, such as in the case of personal use vehicles for baseline calculations.

As such, the quantification methodology presented below is based on the use of emission factors. Emissions for all transit project emission sources can then be calculated using the following generic equation:

Equation 3: $\textbf{GHG emissions}_{\text{emission source}} = \textbf{Activity Level}_{\text{emission source}} \textbf{ X Emission Factor}_{\text{pollutant}}$

The activity level is a measure of an activity that results in GHG emissions for a particular emission source (a common emission source for transit projects is vehicle fuel combustion; other common sources are described in section 4.0). The activity level could be liters of fuel consumed, km driven, hours operated, or any other metric relevant to the particular process or emission source being quantified. The emission factor estimates the rate at which the pollutant generated by the activity is released into the atmosphere.

Emission factors for common vehicle types are included in Appendix 4 for use in transit project quantification. However, projects may choose to include other vehicle types. In this case, emission factors for any additional vehicle types would need to be considered as part of the transit project's quantification exercise.

The emission factor for electricity grid emission is typically based on a provincial average, as per data from Canada's GHG Inventory. This is provided in Appendix 4. A combined margin approach where both the operating and build margins are considered is an alternative (in Alberta, the combined margin will result in a lower emission factor than the provincial average).

Quantifying project benefits tends to be more straightforward for efficiency projects than for modal shifting projects. As a result proponents of modal shift projects should keep in mind the following three special considerations as they review the recommended quantification approach described below:

> *The quantification methodology for modal shift projects assumes that approaches are available for assessing changes in ridership for all relevant vehicle types / modes.*

Special Considerations for Modal Shift Projects

Transit Ridership

The fundamental driver and primary source of benefit for most modal shift projects is to increase public transit ridership levels (the exception being that some modal shift projects may be based on switching modes of travel while maintaining static ridership). As such, successful quantification of emission reductions relies on assessments of changes in ridership between baseline and project cases. This is perhaps the most challenging metric to quantify for modal shift projects, and the one that will receive the most attention from stakeholders. *Approaches used to estimate ridership in various jurisdictions are summarized in Appendix 2: Various Approaches to Predicting Ridership.*

Multiple Modes, Multiple Systems

The transport of passengers from origin to destination may require transfers between different types of transit vehicles / modes, possibly spanning multiple transit systems or jurisdictions. To assess project benefits, each mode of travel needs to be considered separately as different modes will likely emit different levels of GHGs, and special effort may be required to track the movement of passengers across multiple jurisdictions with potentially different data collection systems.

Quantifying the 'Delta'

Two approaches can be taken to quantify emission reductions for modal shift projects involving changes in ridership.

The first approach quantifies emissions from all vehicles in all modes of public and personal travel affected by the project, for both the project and the baseline case. This requires an understanding of total passenger-kilometers and vehicle-kilometers travelled in project and baseline cases by personal and transit vehicles in the geographic area that the modal shift draws on. Access to data on personal vehicle use and total distances travelled in particular can be difficult to find, and as such this approach is not always practical.

Instead, precedent has been set to focus on emissions associated with the mode change(s) only. In this approach, in the case of transit projects, only emissions resulting from the anticipated change in ridership are quantified. Changes in passenger-kilometers travelled due to the transit project are translated into the number of vehicle-kilometers that would have been travelled in the baseline case using a number of assumptions (e.g. typical vehicle occupancy). This approach is discussed in further detail in section 6.6.1.

The quantification exercise focuses on activities with emissions that change between the project and the baseline case.

Focusing solely on emissions associated with the mode change(s) between baseline and project is currently used within Alberta's offset system by the *Quantification Protocol for Modal Freight Shifting*[9] protocol.

6.0 GHG QUANTIFICATION METHODOLOGY

A step-by-step approach is used to quantify emissions for Alberta's transit sector, illustrated in Figure 4 below.

The first step in the process is to describe the project and the key activities it involves. The project description will be used by others to understand and potentially evaluate your project.

This step is followed by a systematic process to identify your project's emission sources, to choose your baseline scenario(s), and to identify baseline emission sources (steps 2, 3, and 4).

Once the emission sources for both the project and baseline are known, they are analyzed to ensure that focus is placed on those activities that result in a change in emissions between the project and the baseline case. Emission sources that result in a significant change in emissions between the project and the baseline are deemed "relevant" and are selected for quantification (step 5).

Emissions from the sources selected are separately quantified for the project and the baseline case (step 6).

Emission reductions are calculated by subtracting baseline emissions from project emissions (step 7).

Any data that needs to be captured (monitored) during the course of the project, the frequency at which it should be captured, and the methodologies to do so are documented in monitoring plans (step 8). Data quality procedures are developed (step 9). Note that steps 1 to 9 are ideally completed before the project is implemented, to help ensure that the right kinds of data are collected during the project to allow for accurate emission calculations. Before the project, emission reductions would be estimated based on expected project performance; during / after the project, actual monitored data would be used in calculations.

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[9] Carbon Offset Solutions (November 2008). *Quantification Protocol for Modal Freight Shifting.* http://www.environment.alberta.ca/documents/Modal_Freight_Shift_Protocol_v1_1_Nov_08.pdf, accessed December 2008.

Finally, the project is implemented. The GHG results of the project are documented and reported.

Detailed methodologies for each of the steps described above are included in the following sections. In addition to the steps presented, it is recommended that project proponents adhere to common GHG quantification concepts designed to increase the accuracy and credibility of the calculations, as discussed in Section 2.0.

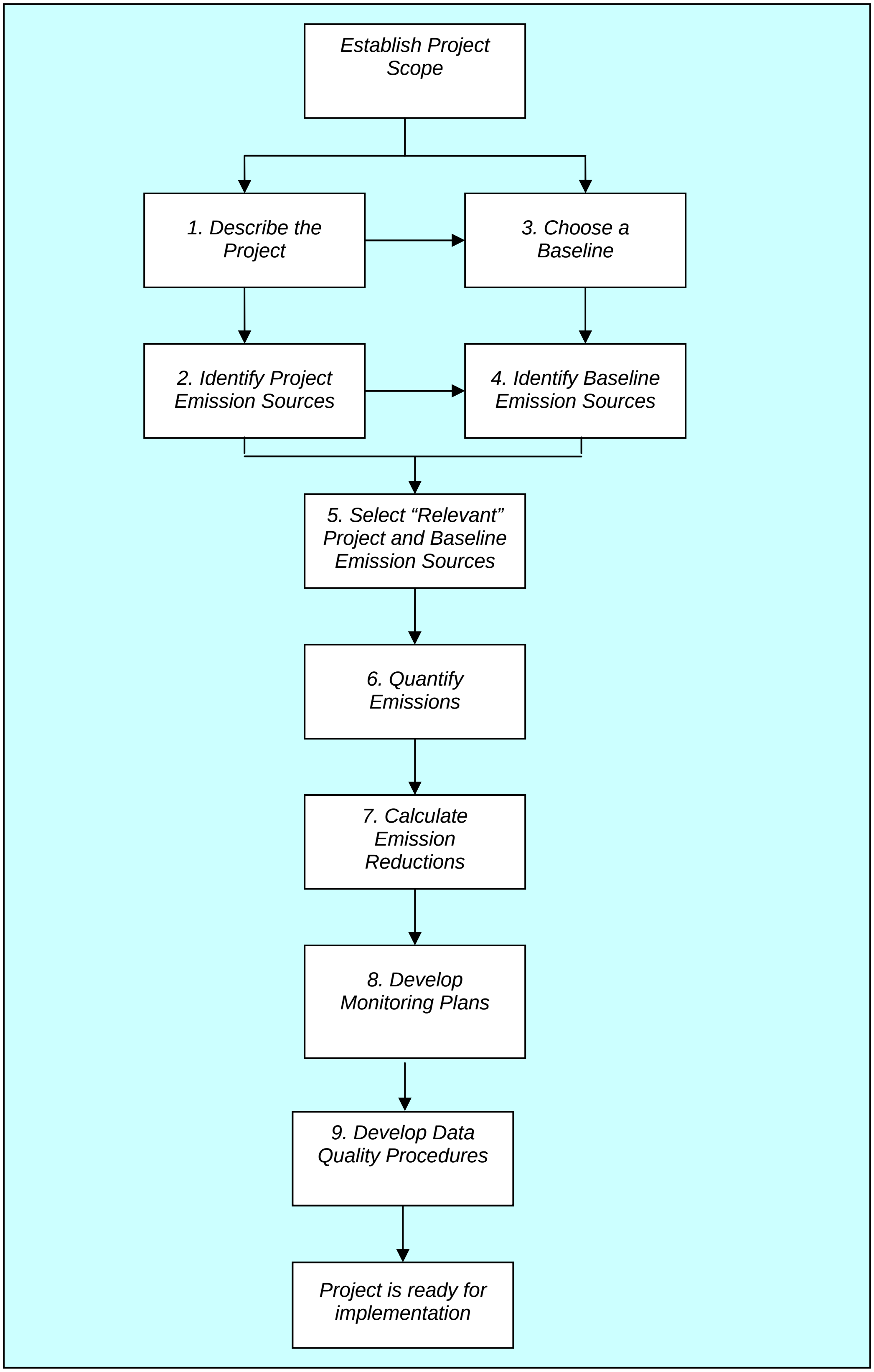

Figure 4: Flow Diagram for Quantification Methodology

6.1 STEP 1 – DESCRIBE THE PROJECT

The first step in quantifying emission reductions for any project is to describe the project undertaking and key activities involved. This description will form the basis for confirming relevant emission sources, and will help others who review your quantification to understand and evaluate the appropriateness of the calculations. Key elements of a project description can include, but are not limited to:

- The project's purpose and objectives;
- How the project intends to reduce emissions;
- Any key technologies, products or services that will be used;
- Project location
- A project workplan / schedule
- Contact information for key project staff, including the person responsible for preparing the GHG quantification

Output from Step 1:

- ➢ Project description complete.

6.2 STEP 2 – IDENTIFY PROJECT EMISSION SOURCES

Once the project is described, the next step is to identify potential emission sources.

The transit emission sources identified in Section 4.0 can be used as a starting point, but it is recommended that this list be refined based on the main project activities. Ideally, a systematic approach will be used to ensure that a complete assessment of potentially relevant emission sources is conducted. One potential approach, based on standard lifecycle assessment procedures, would include the following steps:

- identify the main activities that immediately provide for a transit system's function (e.g. bus operation, LRT operation, transit facility operation, etc., which are typically controlled by the project proponent);
- identify inputs and outputs (materials and energy) associated with these main activities (e.g. different types of fuel, electricity, etc.);
- identify additional potentially relevant activities by tracking identified material and energy inputs/outputs upstream to their origins in natural resources or downstream along the life-cycle (these activities would not typically be controlled by the project proponent, but would still be related to project activities); and
- review all activities and material and energy flows to ensure that all relevant activities have been identified.

Use illustrative diagrams and tables wherever possible to help organize information and make the process more transparent. Note that at this stage, you may end up identifying some emission sources that you later decide are not relevant and do not need to be calculated. This is ok, and is better than omitting relevant emission sources.

Output from Step 2:

- ➢ List of potentially relevant project emission sources.

6.3 STEP 3 – CHOOSE A BASELINE

As noted previously in Section 2.0 of this guide, the baseline represents a *hypothetical* scenario that occurs over the same timeframe as the project, but represents what would most likely have occurred in the absence of the project. The baseline is the comparison case against which changes in emissions due to the project are assessed.

Functional Equivalence

It is critical that the project and baseline offer the same types and levels of service in order to ensure that a fair "apples-to-apples" comparison is performed. This is referred to as ***functional equivalence***. (i.e. the project and baseline need to be functionally equivalent). In most transit project cases, the service provided will be the transport of passengers and baseline cases will naturally provide this function if they include various transport modes.

The concept of functional equivalence is also important for transit facility energy efficiency projects. Transit facility energy consumption can be influenced by many factors beyond those that are the focus of a particular project. For instance, energy consumption for building heating is dependant not only on the efficiency of the heating system, but also the climate for that particular year (e.g. colder winter = more heating required). In the case of electricity use, building occupancy levels can affect electricity usage in addition to equipment energy efficiency. This can create problems where a net emission reduction is determined by comparing current energy usage to historic usage. To ensure functional equivalence, historic baseline data should be adjusted for any changes in key factors between the historic timeframe and the project timeframe. Readers are referred to the International Performance Measurement and Verification Protocol (IPMVP), 2007 edition, for further details on how to address this issue.

In identifying the baseline, it is important to consider the services provided by the project and ensure that the baseline provides equivalent types and levels of service. Baseline conditions will be extrapolated for the project's lifetime in order to determine the emissions that would have occurred in the absence of the project.

Types of Baselines

The simplest approach to baselines is to assume that the conditions that existed prior to implementing the project (i.e. the historic case) would have continued into the future for the duration of the planned project. For instance, for an efficiency project this could include an ageing fleet of buses that will be replaced by more efficient project buses, and for a modal shift project this could include personal car and truck travel from point A and B that was required prior to constructing a new project LRT line.

Continuation of past activities, however, is not always the most likely case in the absence of the project. For instance, what if that ageing bus fleet was at the end of its serviceable life and needed to be replaced anyways (presumably with newer, more efficient vehicles)? You could still calculate project emission reductions relative to the historic case, but this would likely overestimate the benefits of the project and may not be acceptable to key stakeholders.

As a result, the recommended approach to baseline selection is to consider a range of potential ways in which the project service could be provided in the absence of the project. This would likely include the continuation of historic practices, but could also include a range of other options. Ideally, the new project activity would also be considered as a potential baseline, to ensure that the planned project is not already considered "business-as-usual" and thus would not result in any new emission reductions beyond what would have happened anyways.

Each identified baseline option would then be assessed against different criteria to determine which would be most likely to proceed in the absence of the project. For example, potential barriers to different options proceeding (e.g. financial cost, customer service issues, complexity, etc.) could be used as criteria, and the option with the least barriers would be selected as the most likely scenario (this approach is referred to as a “barriers test”).

Some additional examples to help you with selecting an appropriate baseline are provided below.

Sample Scenario – Efficiency Project

Consider the case of a vehicle efficiency project that aims to retire aging diesel buses that have five years left before the end of their serviceable life and replace them with new hybrid diesel-electric buses with a life expectancy of 18 years. For the first five years of the project, an historic baseline would probably be most appropriate since the old buses would still have been operated for 5 more years. However, after the fifth year, the baseline would ideally be re-evaluated since various options would have been available in the absence of the project, including:

- Refurbishing / extending the life of the old buses
- Purchasing new diesel buses
- Purchasing new alternative fuel (i.e. lower emission) buses
- Etc.

As the project proponent, you might decide for simplicity to still use the old historic baseline in your calculations, even if the old buses would have likely been retired. However, if more accuracy is required, these additional baseline options could be considered.

Sample Scenario – Modal Shift Project

Suppose a transit jurisdiction is considering extending an LRT line. The existing LRT line currently serves 500,000 passengers per year. The addition of the new line segment is expected to result in servicing 50,000 additional passengers per year. The new segment of the line is expected to have a life expectancy of 35 years.

A number of different baseline scenarios can be considered, such as:

Baseline 1 (Historic): The current transit configuration is maintained for the project duration. This configuration is used to determine the GHG emissions that would result in the absence of the project. In absence of the project, the current 500,000 passengers continue to use the existing transit system. The 50,000 passengers that would have been served by the new LRT line segment continue to travel by their original mode of transport.

Because the 500,000 existing LRT passengers travel by LRT in both the project and the baseline case, there would be no change in their emissions between the project and baseline, and thus they do not need to be quantified (assuming that LRT emissions per passenger are not altered by the project). Emissions calculations can thus focus on the change in ridership projected – namely the 50,000 new passengers. All pre-project travel modes used by these new passengers need to considered. For example, it might be determined that 70% drive, 25% take existing transit buses, 3% bike and 2% walk. Emissions resulting from these baseline travel modes (such as those due to fuel combustion by transit and personal use vehicles) would then be projected out for the project duration of 35 years.

Baseline 2 (Projection): Perhaps it is not appropriate to assume that past conditions would have continued for the project duration. For instance, if the transit system is expected to experience a steady rate of ridership increase even without the LRT extension, it might be appropriate to update the baseline modal breakdown over time during the project. In this case, for instance, it might be appropriate to assume that the ridership on existing buses (25% at the start of the project) would increase by 2% per year (i.e. 25.5% in year 2, 26% in year 3, and so on) at the expense of the other modes, primarily cars and trucks. This type of year-over-year adjustment is sometime referred to as a dynamic baseline.

Output from Step 3:

- Baseline scenario selected.

6.4 STEP 4 – IDENTIFY BASELINE EMISSION SOURCES

Once a baseline is selected, it is then possible to identify associated emission sources. To again ensure that an "apples-to-apples" comparison is being performed, baseline emission sources should be identified in a manner consistent with the project. Since both the project and baseline will be providing transit services, many of the emission sources will be the same (though their associated levels of activity will be different in some cases). However, some differences will likely be present with respect to new vehicles or facilities included in the project but not the baseline case.

For further guidance on identifying baseline emission sources, see step 2, above.

Output from Step 4:

- List of potentially relevant baseline emission sources.

6.5 STEP 5 – SELECT "RELEVANT" PROJECT AND BASELINE EMISSION SOURCES

Once a potential list of emission sources has been identified for a project and its baseline, it is important to decide which emission sources are relevant to calculating emission reductions and which could be excluded. Obviously, eliminating irrelevant emission sources will simplify the quantification.

The recommended approach is to compare project and baseline emission sources (for instance in a table, where similar project and baseline sources are placed side-by-side) and then apply criteria for determining relevance.

While specific criteria for determining relevance can vary and will depend on the intended uses of and audiences for the quantification, three common approaches are as follows:

1. **No change between the project and the baseline case**
   Where a project does not result in a change to a particular emission source relative to the baseline case, there is no need to consider the associated emissions when calculating net emission reductions. For instance, in the case of a project focused solely on improving transit vehicle efficiency, there would be no need to consider emissions associated with heating and lighting buildings, which would remain unchanged.

   Sometimes it is not always clear whether or not there is a difference between a particular emission source in the project and baseline. For instance, take the case of a modal shifting project involving expansion of an existing LRT line. In this case, it might be tempting to exclude emissions from the existing portion of the LRT line since it is present in both the project and baseline case, and the project is focused on building a new section of LRT line. However, if new transit riders in the project ride not only the LRT expansion, but also the original line as well, then there will be an impact on emissions from the old line relative to the baseline as additional fuel will be required to move these

new passengers on the old line. In this case, it would be recommended that emissions from the original LRT line be considered as relevant in both the project and the baseline.
However, in the same example, assuming that all new riders come from cars and trucks, it would be appropriate to only focus only on the cars and trucks driven by the passengers doing the mode shift, versus all cars and trucks on the road. This is because the act of mode shifting doesn't have any impact on the emissions from the other cars and trucks (unless reduction in traffic congestion were considered for very big projects), and thus there is no change between the project and baseline for those emission sources.

2. **Insignificant relative to other sources**
   Depending on the desired level of accuracy and available resources, it may be practical to restrict calculations to major emission sources that represent the majority of emissions, rather than calculating each and every emission source regardless of size. If this approach is taken, it is recommended that for consistency and transparency a clear set of rules be established regarding how significance is determined, particularly since "significance" is a subjective term that means different things to different people. For instance, a threshold could be established below which an emission source would be excluded from consideration – e.g. exclude emission sources that each represent less than 5% of total emission reductions, or that collectively represent less than 10% of emission reductions. Another approach could be to decide that certain types of emission sources, for example one-time equipment and infrastructure manufacturing / construction / decommissioning emissions, could all be excluded since these sources are typically small in comparison to on-going emission sources.

3. **Project emissions less than baseline emissions**
   An emission source that otherwise would be relevant based on criteria 1 and 2, above, could still be excluded from quantification where project emissions are less than baseline emissions for the particularly emission source. This is because excluding such an emission source would result in a decrease in overall emission reductions, which would satisfy the conservativeness principle described in Section 3.4. Excluding an emission source in this case might be warranted where the expected emission reductions due to that emission source were relatively minor compared with the cost or effort required to gather the necessary data for its quantification.

Regardless of the criteria used, the more transparently they are presented, the more credible your emission calculations will be. The following example table illustrates these concepts.

Table 1: Emission Source Selection

Project Source	Baseline Source	Relevant?	Rationale
Source 1	Source 1	No	No change in emissions between project and baseline
Source 2	No equivalent baseline source	No	While project emissions are greater than baseline (no baseline emissions in this case), these emissions are expected to be < 0.5% of total emission reductions (see sample calculation) and thus are not considered relevant.
Source 3	Source 2	Yes	Significant change between project and baseline, should be quantified.
Source 4	Source 4	No	Project emissions < baseline emissions; will be conservatively excluded.

The table below provides an overview of common emission sources likely considered as part of transit efficiency projects and notes regarding relevance. Quantification methodologies for the main project and baseline sources are provided in section 6.6 below.

Table 2: Transit Project Emission Sources

Project Emission Sources	**Notes**
Vehicle Fuel Combustion	Primary emission source for fossil fuel based vehicles.
Grid Electricity Generation for Electric Vehicles	Primary emission source for electric vehicles.
Fuel Extraction and Production	Upstream emission source for vehicle operation and facility operation; can be significant, but much less than direct combustion emissions. Project emissions likely < baseline emissions.
Fuel Transportation	Upstream emission source. Very small compared to fuel combustion and fuel extraction and production emissions; likely reasonable to exclude based on significance. Project emissions likely < baseline emissions.
Vehicle Decommissioning*	Vehicle decommissioning is likely either equivalent to the baseline case or insignificant over the lifetime of the project.
Vehicle Maintenance	Likely equivalent to baseline case and so can be justified for exclusion in most projects.
Transit Facility Operation	Primary emission source for facility-focused projects. For projects where there is no change to facility operation (e.g. vehicle efficiency, modal shifting without enhanced facility infrastructure), likely no change between project and baseline and can thus be excluded.
Transport Infrastructure Construction	Likely negligible over a project's lifetime, unless the project is focused on improving transport infrastructure.
Transit Infrastructure Maintenance	Likely equivalent to baseline case and so can be justified for exclusion.
Transit Facility Construction	Relevant for projects that include new transit facilities, however, likely negligible over a project's lifetime compared to other emission sources.
Facility Decommissioning	Relevant for project and baseline scenarios including transit facilities, though any differences between project and baseline likely negligible over a project's lifetime.

**In cases where vehicles or equipment being replaced are sold to other transit systems instead of being permanently retired, there is a chance that they will be operated instead of more efficient, newer vehicles or equipment, thereby diminishing the GHG emission reductions achieved by the project. While a transit project developer would not reasonably be expected to account for these emissions in a detailed way for their project, the possibility of such a scenario should be considered and avoided wherever possible.*

Output from Step 5:

- List of relevant project and baseline emission sources selected for quantification.
- Rationale for the exclusion of any emission sources.

6.6 STEP 6 – QUANTIFY EMISSIONS

Quantifying emissions is the most involved step in the overall quantification process, and may seem overwhelming to those for whom this is a relatively new exercise. It is perhaps helpful to consider that ultimately the endpoint of Step 6 will address the following questions:

- What emissions are quantified?
- When are emissions quantified?
- How are emissions quantified?

***Reminder**: Both baseline and project emissions are calculated over the same time period. Baseline emissions will be subtracted from Project emissions in Step 7 to determine a project's emission reductions.*

6.6.1 WHAT NEEDS TO BE QUANTIFIED?

Emissions need to be quantified for:

- The project
- The baseline

Emissions generated from each of the project emission sources selected as relevant in Step 5, above, need to be quantified for the project duration. Total project emissions are then calculated as the sum of the emissions from each of the project emission sources selected, using the following equation.

Equation 4: $\textbf{Emissions}_{\text{project}} = \textbf{Emissions}_{\text{source 1}} + \textbf{Emissions}_{\text{source 2}} + \ldots + \textbf{Emissions}_{\text{source n}}$

where n = the number of project emission sources to be quantified.

Similarly, emissions generated from each of the baseline emission sources selected in Step 5, above, need to be quantified for the project duration. Total baseline emissions are then calculated as the sum of the emissions from each of the baseline emission sources selected, according to the following equation, analogous to Equation 4.

Equation 5: $\textbf{Emissions}_{\text{baseline}} = \textbf{Emissions}_{\text{source 1}} + \textbf{Emissions}_{\text{source 2}} + \ldots + \textbf{Emissions}_{\text{source n}}$

where n = the number of baseline emission sources to be quantified.

Modal Shift Projects: Quantifying the 'Delta'

In the case of modal shift projects, it may be impractical to calculate total project and baseline emissions (i.e. emissions from all vehicles in all modes of public and personal transit affected by the project). Instead, it might be simpler just to focus on emissions associated with the mode change(s).

For example, consider an LRT extension project that is expected to service 50,000 new transit passengers a year by shifting them from other transport modes. Rather than calculate emissions for the complete expanded LRT line (existing LRT plus the extension) plus all cars and trucks on the road for both the project and baseline, it may be simpler to calculate emissions for the new section of the line and those vehicles previously driven by the 50,000 new transit passengers **only**. Don't

Modal Shift Projects: Quantifying the Delta
For modal shift projects, project and baseline emissions calculations can focus on quantifying emissions resulting from the mode change only.

forget, however, that *if emissions for the project are limited to the mode shift, then emissions for the baseline are also limited to the mode shift*.

If emissions are isolated to the mode shift, then calculations are based on the difference in activity levels directly attributable to the mode shift, in this case emissions due to the transport of 50,000 passengers:

- in the project case only those emissions resulting from the transport of the 50,000 new passengers on the LRT extension would need to be calculated.
- in the baseline case, only the emissions due to the transport of those 50,000 passengers on baseline travel modes (which could be split between personal use vehicles, transit buses, bicycles etc.) need to be calculated.

If emissions calculations are not limited to the mode shift, but instead consider the entire project (i.e. the entire LRT line), then calculations will most often be more involved.

- In the project case, emissions resulting from the transport of all passengers on the entire line need to be calculated.
- In the baseline case, the baseline scenario would need to consider how the ridership for the existing LRT **plus** the new extension would have travelled, and then calculate emissions from those modes.

Note: special care must be taken when performing emissions calculations based on the difference in activity levels, as the risk increases that either relevant emissions will be missed (for example if the baseline modes are not properly accounted for), or that emission changes may be inadvertently double counted.

Methodologies provided for mode shift projects below can be applied to entire projects, or to the component related specifically to the mode change only.

***Reminder**: The project and the baseline MUST measure the same thing.*

The unit of measure for most transit projects will usually be in passenger-kilometers (PKM).

PKM project = PKM baseline (see note)

HOW those PKM are travelled will be different. PKM travelled in the project case may be entirely on public transit vehicles, while PKM travelled in the baseline case will likely contain multiple modes of travel, including both transit and personal use vehicles. SO, if a project is anticipated to increase ridership (and thus increase PKM), any historical monitored baseline data (e.g. fuel consumption) needs to be scaled to the project's PKM levels to ensure the baseline measures emissions for the same PKM levels as the project.

For vehicle efficiency projects, where the number of PKM transported are the same in the project and baseline, vehicle-kilometers (VKM) travelled can be used to quantify emissions. In this case:

VKM project = VKM baseline

6.6.2 WHEN DO EMISSIONS NEED TO BE QUANTIFIED?

The quantification exercise is usually repeated several times over the course of a project:

- Before project implementation
- During a project's lifetime
- At the end of a project's lifetime.

The first time emissions are quantified is typically *before* project implementation. In this case, numbers for most of the parameters will need to be estimated or calculated (though some actual baseline data may be available). The results of this initial quantification exercise are used to assess the potential GHG benefit of a project.

Reductions can also be quantified periodically *during* a project's lifetime, once a project is implemented. Access to actual (monitored) data is expected to be more readily available and can be used to track how well a project is performing relative to expectations. Interim reports would typically be prepared to summarize results to date.

Finally, the quantification exercise is repeated at the *end* of project. A report is usually generated that will present the actual emission reductions that were realized, versus the emissions reductions that were estimated as part of the first quantification exercise.

6.6.3 HOW ARE EMISSIONS QUANTIFIED?

As described in section 5.2, emissions are quantified by applying an emission factor to relevant activity levels for each of the project and baseline emission sources selected for quantification.

This guide provides calculation methods for the emission sources listed in Table 3 below. Please see section 4.0 for a detailed description of each of the emission sources included.

Table 3: Emission Source Calculation Methods Included in this Guide

Emission Source	Vehicle Efficiency Projects	Transit Efficiency Projects	Modal Shift Projects
Vehicle Fuel Combustion	✓		✓
Grid Electricity Generation for Electric Vehicles	✓		✓
Fuel Extraction and Production	✓	✓	✓
Transit Facility Operation		✓	✓

Emissions from the above sources are primarily generated as a result of three activities:

- fuel combustion,
- electricity consumption,
- fuel extraction and production.

Methodologies to quantify emissions for these activities are the same regardless of whether the source of the emission is due to vehicle use, to fuel extraction and production, or to transit facility operation. Only the emission factor that applies needs to be changed.

Detailed methodologies for emissions resulting from fuel combustion, electricity generation and fuel extraction and production are provided in the sections below. Note that the methodologies developed for modal shift projects are based on the following assumptions regarding trip length and ridership:

Assumptions for Modal Shift Projects

1. Trip lengths travelled on transit systems and personal travel routes are the same.[10]
2. Changes to ridership are assumed to occur as a result of the transit modal shift project. Changes to ridership levels due to external factors such as fuel price are not considered.

The following data (estimated, calculated or monitored) is also expected to be available as an input to the project quantification exercise for modal shift projects.

1. Baseline ridership levels (i.e. ridership in the absence of project).
2. Change in ridership due to modal shift project (i.e. number of new transit passengers due to project).

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[10] Transit operators may choose not to make this simplifying assumption.

It is recognized that obtaining accurate data on ridership levels may pose a challenge. An overview of approaches used to estimate ridership used in various jurisdictions is provided in Appendix 2[11]. However, it is critical to note that the accuracy of a modal shift project's GHG emissions quantifications is directly tied to the accuracy of ridership levels used in its calculations.

The accuracy of a modal shift project's predicted GHG emissions reductions is directly tied to the accuracy of the ridership levels used in its calculations. This includes baseline ridership levels, as well as ridership changes directly attributable to the mode shift.

6.6.4 FUEL COMBUSTION

As described in section 6.6, emissions are quantified by multiplying a relevant activity levels applying an appropriate emission factor. In the case of fuel combustion, these are:

Activity: the combustion of fossil fuels (as well as alternative fuels such as biofuels) resulting from vehicle use or transit facility operation.

Activity level: a measure of the amount of fuel combusted. This is typically in liters but can also be in other volumetric measures such as cubic meters (as is usually in the case of natural gas), or non-volumetric units such as mass (e.g. kg, tonnes, etc.) and energy (e.g. gigajoules, BTU, etc.).

Emission Factor: Different emission factors exist for different fuel types (e.g. diesel, gasoline, heating fuel), and for different vehicle categories (e.g. public transit buses, light rail etc.). However, differences between vehicle categories using the same type of fuel are quite minor, since vehicle type does not influence the amount of CO2 emitted (representing the vast majority of combustion-related GHG emissions), but rather only the CH4 and N2O combustion emissions, which are influenced by individual vehicle emission control systems.

Biofuels

CO_2 emissions resulting from biofuel use are considered GHG neutral, because from a carbon cycle perspective, the carbon in the biofuel was taken from the atmosphere to grow the feedstock, and would have naturally returned to the atmosphere via decomposition if not for its use in producing biofuel. However, as with fossil fuel combustion, combustion of biofuels also results in the release of methane (CH_4) and nitrous oxide (c), which would not have occurred in the natural decomposition process. A rigorous quantification of biofuels emissions would need to account for CH_4 and N_2O emissions. This can be done using the methodologies provided here and the emission factors provided in Table 8.

Where the fuel used is a biofuel mix (e.g. E10, B20, E85), CO_2 emissions resulting from the combustion of the non-biofuel component of the mix need to be calculated.

Upstream emissions (e.g. emissions related to agricultural practices, fertilizer production, etc.) are a significant emission source for biofuels and should be included in calculations.

As such, calculations would need to be repeated for each relevant fuel type, and ideally for each relevant vehicle type in the project and baseline.

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[11] Ridership data resulting from modal shift projects may not always be well understood. Rationale for values used in calculations needs to be transparently documented, even if they can not be formally substantiated.

For completeness, quantities of fuel combusted for vehicle operation should include:

- Fuel combusted during transport of passengers
- Fuel combusted while idling
- Fuel combusted while driving with an empty vehicle, where such driving is a direct result / requirement of transporting passengers

Quantities of fuel combusted can be determined using a number of methodologies, based on different activity data sources. Two potential methods are introduced below, and then described in more detail in the following sections.

- **Method A**: Monitored or estimated fuel consumption data

  In Method A, quantities of fuel combusted are either monitored or estimated. Monitored data on fuel consumption may be available for the baseline case, as well as for the project case once the project is implemented. Monitored data is aggregated to provide a value for the time period that is being reported (typically annually). Fuel consumption levels can also be estimated, usually based on historical consumption trends. Note, however, that historical consumption levels may need to be adjusted to account for functional equivalence, as described above. Data sources for fuel consumption data are provided in Table 4: Activity Data Sources, in Section 6.6.7.

- **Method B**: Derived fuel consumption based on distance (VKM, or PKM plus an assumption of typical vehicle occupancy) travelled and vehicle efficiencies.

  In the derived fuel consumption method, distances travelled are multiplied by a vehicle fuel efficiency factor to determine quantities of fuel combusted. Data sources for distances travelled are provided in Table 4: Activity Data Sources.

*The quantity of fuel used in project calculations is the quantity of fuel combusted that is **directly attributable** to project implementation. In the case of modal shift projects, the quantity of fuel used in calculations corresponds either to fuel combustion that occurs solely because of the mode shift or to the fuel combustion from the entire project, as long as functional equivalence is maintained.*

6.6.4.1 Description of Calculation Methods

As described above, emissions due to fuel combustion can be calculated using two methodologies, based on different activity data sources. Please note that where volumetric units are specified in the methods that follow, mass or energy-based metrics could be used instead.

Method A: Calculations Based on Fuel Consumption Data

This method can be used to quantify emissions from *vehicle fuel combustion* and *transit facility operation*, if monitored or estimated fuel consumption data is available. Emissions using this method can be calculated by completing the steps below.

1. *Gather fuel consumption data*. A detailed set of potential sources for fuel consumption data is listed in Table 4: Activity Data Sources, in Section 6.6.7. In the case of fuel combustion due to transit facility operation, common potential data sources include heating bills and meter readings. In the case of vehicle fuel combustion, data should be gathered by vehicle type and at minimum by fuel type. Potential sources may include fuel receipts, financial records of fuel expenditures, or direct

measurements of fuel use.[12] For both vehicles and facilities, fuel consumption data can also be estimated based on historical data, manufacturer claims on efficiency, etc.

Where historical data are to be used, special care should be taken to ensure that:

- Functional equivalence is maintained between the project and the baseline. One approach in this regard is to convert historic fuel consumption data to a fuel consumption rate per passenger-km transported, which then allows it to be scaled according to the amount of PKM transported in the project case. For instance, the following equation could be used in a modal shifting example:

  Equation 6: Fuel Consumption due to Modal Shift (L) = (Fuel Consumption for Baseline Transit Ridership (L) / Baseline Transit Ridership) X Increased Project Ridership

- The historic data is relevant during the project timeframe. Prior to using historic data directly, it is necessary to ensure that it is still valid during the project timeframe. For instance, Equation 6 would only apply where the increased ridership did not alter the fuel consumption of the baseline transit vehicles. If, for instance in the case of a bus fleet, the increased ridership significantly increased the average bus occupancy, the amount of fuel consumed per PKM would decrease as a result of the project.

Regardless of the approach used, any assumptions made in the calculation process should be clearly documented.

2. *Convert fuel consumption from Step 1 to GHG emissions by multiplying by the appropriate fuel-specific emission factor.* The following default emission factors are provided in Appendix 4: Default Data Tables:
   - Heating fuel emission factors: Table 8
   - Vehicle specific fuel combustion emission factors: Table 6

   An appropriate emission factor and the fuel consumption value from Step 1 would then be used in the following equation to calculate emissions for fuel combustion.

Equation 7: GHG emissions (kg CO2e) = $\sum_{\text{type}}$ Fuel Consumption (L) X Fuel Combustion Emission Factor (kg CO2e / L)

where

Type = fuel type per facility or vehicle type

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[12] World Resources Institute (WRI), The Greenhouse Gas Protocol Initiative (2005). Calculating *CO2 Emissions from Mobile Sources Guidance Document v1.3*. http://www.ghgprotocol.org/calculation-tools/all-tools, accessed October 29, 2008.

The volume of fuel combusted for transit facility efficiency projects can be influenced by many factors outside the focus or control of a particular project. For instance, energy consumption for building heating is dependant not only on the efficiency of the heating system, but also the climate for that particular year (e.g. colder winter = more heating required). Readers are referred to the International Performance Measurement and Verification Protocol (IPMVP), 2007 edition for further details on how to ensure functional equivalence and address this issue.

Method B: Derived Fuel Consumption Based on Distance Travelled and Vehicle Efficiency Factors

This method is not applicable to the transit facility operation emission source as it relies on distance.

This method can be used to quantify emissions from the *vehicle fuel combustion* emission source when monitored or estimated fuel combustion data is not available. In this case, the quantity of fuel combusted can be derived based on vehicle distances travelled and vehicle fuel efficiencies.

Emissions using this method can be obtained by completing the steps below.

1. *Collect data on vehicle kilometers (VKM) travelled by vehicle type.* Since vehicle fuel efficiencies are typically reported in fuel consumed per km travelled, it is necessary to determine the number of VKM travelled by each vehicle type in order to calculate emissions using Method B. VKM can either be taken directly from monitored data, or it can be derived using various approaches, including based on passenger-kilometers (PKM) travelled and assumptions regarding typical vehicle occupancy, and trip length and number of trips.

   Regardless of the approach, care must be taken to ensure functional equivalence between project and baseline. Where there is no change between project and baseline vehicle capacity, and thus the same number of VKM will be travelled in both the project and baseline case to deliver the same number of PKM (e.g. as could be the case in a vehicle efficiency project), then project VKM can be assumed equal to baseline VKM. Otherwise, it would be necessary to estimate at minimum baseline VKM (and also project VKM if desired) based on PKM and occupancy assumptions for the vehicle types in question.

   Potential approaches to quantify VKM are described below.

   1.1. *Direct measurement of VKM travelled by vehicle type.* If monitored records are available for VKM travelled by project vehicles (e.g. from odometer readings), these should be used. It is, however, unlikely that monitored baseline data (e.g. historic records if appropriate) could be used directly since PKM travelled in the project would likely be different that PKM travelled in the past. Thus, another option would need to be used for baseline VKM.

   1.2. *Calculate VKM travelled by vehicle type.* This approach can also be used to determine project VKM in the absence of monitored km data. However, the same limitation regarding the use of this method for baseline VKM as encountered in the direct measurement approach, above, applies in this case as well. The formula below may need to be modified slightly to consider varying daily trips made depending on the day of the week, and may be difficult to implement for complex transit systems give the number of different routes and numbers of trips.

   Equation 8: VKM = $\sum_{\text{transit route}}$ Transit Trip Length (km) * (Number of Trips / Day) * 365 Days / Year

1.3. *Derive VKM travelled by vehicle type based on PKM travelled and vehicle occupancy assumptions*. If a project involves switching to transit vehicles that carry different numbers of passengers than baseline transit vehicles, switching from non-transit to transit vehicles, or an increase in ridership, then PKM are used, at least in the baseline case and optionally for the project case, to determine the number of VKM travelled. This approach is described below.

1.3.1. *Determine PKM travelled.* Post project implementation, transit authorities may have monitored data on PKM travelled either for the entire project, or directly resulting from the modal shift (e.g. from passenger surveys). Table 4 below captures potential data sources for PKM. If monitored data is not available (e.g. pre project implementation), then changes to ridership levels need to be estimated and translated into PKM. See Appendix 2: Various Approaches to Predicting Ridership for an overview of approaches used to estimate ridership in a variety of jurisdictions. The equation below is one way of estimating additional PKM travelled as a result of an estimated/monitored increase in ridership. Data sources for trip length are included in Table 4 below.

Equation 9: PKM due to mode shift = $\sum_{\text{trip route}}$ **Change in ridership (# new passengers) * Trip length (km)**

1.3.2. *Convert PKM to vehicle kilometers driven.* Apply typical vehicle occupancy numbers to PKM to convert PKM into VKM. In the case of transit vehicles, transit operators may have monitored data regarding average occupancy. If not, typical occupancy numbers per transit vehicle type need to be estimated, and any underlying assumptions documented. The number of PKM travelled in the project case needs to be carried over to the baseline case, and split out between the travel modes included in the baseline scenario. Project PKM must equal Baseline PKM[13]. Splitting baseline PKM across various vehicle modes will likely be made using assumptions on the % of ridership that formerly drove personal use vehicles and other forms of transit, versus non emitting sources such as walking. Personal use vehicles can be further broken down into vehicle types typically used within a jurisdiction (light duty passenger vehicle, light duty passenger truck etc.). See Table 4 for activity data sources. The following equation is used to determine VKM by vehicle type.

Equation 10: $$\text{VKM}_{\text{vehicle type}} = \frac{\text{PKM}_{\text{vehicle type}}}{\text{Vehicle Occupancy}}$$

2. *Convert VKM travelled from Step 1 into fuel combustion quantities based on vehicle efficiency factors*. This step needs to be repeated for each vehicle type in the project or baseline scenario being quantified (e.g. light duty passenger vehicle, hybrid diesel bus etc). Fuel efficiency factors can be influenced by a number of variables such as vehicle type, age, load (i.e. # of passengers), and road and driving conditions. Greater accuracy for this step can be obtained by applying tailored fuel efficiencies based on varying conditions using assumptions. For example, varied fuel efficiencies based on assumptions regarding the percentage of driving time spent idling, driving in the city, or driving on the highway can be used. Data sources for transit vehicle efficiencies can include company fleet records, including original fleet purchase records.[14] A more complete list of possible data sources is provided in Table 4. Alternately, a list of vehicle fuel efficiencies for a number of vehicle types can be found in Appendix 4. The data source used needs to be reputable and well documented to maintain transparency. Volume of fuel would then be calculated using the following equation.

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[13] The only exception here is for a transit operator who chooses NOT to make the simplifying assumption that the transit and personal travel routes lengths are the same.

[14] World Resources Institute (WRI), The Greenhouse Gas Protocol Initiative (2005). Calculating *CO2 Emissions from Mobile Sources Guidance Document v1.3*. http://www.ghgprotocol.org/calculation-tools/all-tools, accessed October 29, 2008.

Equation 11: Volume of Fuel Combusted (L) = $\sum_{vehicle}$ VKM (km) * Vfe (L fuel/km)

where

- VKM represents the number of vehicle kilometers travelled, and
- Vfe represents the vehicle fuel efficiency.

3. *Convert fuel consumption estimate from Step 2 to GHG emissions by multiplying by the appropriate vehicle-specific emission factor.* The final calculation is made using the following equation, analogous to Equation 7 from Method A, above. Default emission factors are provided in Appendix 4: Default Data Tables, Table 6.

Equation 12: **GHG emissions (kg CO2e) = $\sum_{type}$ Fuel Combusted (L) X Fuel Combustion Emission Factor (kg CO2e / L)**

6.6.4.2 Fuel Switching

Projects involving fuel switching from one type of fuel to another (e.g. switching from diesel to less carbon-intensive natural gas) may need to account for the different energy content of the fuel types involved. This is because different fuels contain different amounts of energy per volume, and it is this energy (and not fuel volume) that is directly related to moving passengers. Thus, different volumes of different fuels are required to deliver the same amount of energy to a vehicle.

If fuel consumption data for vehicles providing the same level of service is separately available for the project and baseline, then the difference in energy content of the fuels will automatically be accounted for and does not need to be considered. In this case the methodologies provided in section 6.6.4 can be directly applied.

However, if fuel consumption data for the project needs to be estimated based on the amount consumed in the baseline (or vice-versa) in a fuel switching project, then you need to work in energy units versus volume units to ensure functional equivalence.

In the simplest case, where there are no changes in energy efficiency between project and baseline vehicles, this is done by multiplying the volume of fuel for the first fuel type by its heating value to convert it into an energy value (e.g. megajoules (MJ) or gigajoules (GJ)). This amount of energy is then converted to an equivalent amount of the next fuel type using the second fuel's heating value. This process is captured in the following equations:

Different fuels provide different amounts of energy per unit of volume. They cannot typically be substituted 1:1 and still provide the same level of service. Projects involving fuel switching will likely need to estimate fuel volumes using energy values.

1. *Convert the volume of fuel type 1 into an energy value*.

   Equation 13: Energy $_{fuel\ type\ 1}$ (MJ) = Volume $_{fuel\ type1}$ (L) X Heating Value $_{fuel\ type\ 1}$ (MJ/L)

2. *The energy provided by both fuel types is the same (assumes no change in energy efficiency)*.

   Equation 14: Energy $_{fuel\ type\ 1}$ (MJ) = Energy $_{fuel\ type\ 2}$ (MJ)

3. Convert the energy value of fuel type 2 into a volume.

   Equation 15: Volume $_{fuel\ type\ 2}$ (L) = Energy $_{fuel\ type\ 2}$ (MJ) / Heating Value $_{fuel\ type\ 2}$ (MJ/L)

Heating values for a variety of fuel types is provided in Appendix 4.

Fuel volumes obtained in this manner can be used in the methodologies provided in section 6.6.4 in order to quantify associated emissions.

However, for projects involving both fuel switching and efficiency improvements, a slight modification is required. While conversion to energy units is still the first step, the energy requirement for the project and baseline would not be set equal in Step 2 of the above process. Instead, the amount of energy for fuel type 2 would be calculated based on the fuel type 1 energy and expected changes in vehicle efficiency. This resulting energy for fuel type 2 would then be converted back to volume units using Step 3, above, and the methodologies in Section 6.6.4 could then be applied as per normal.

6.6.5 GRID ELECTRICITY GENERATION

As described in section 6.6, emissions are quantified by multiplying relevant activity levels by appropriate emission factors. In the case of grid electricity generation, these are:

Activity: electricity that is required to power electric vehicles or transit facilities.

Activity level: a measure of the amount of electricity consumed, typically in units of kilowatt-hours or megawatt-hours (kWh, MWh).

Emission factor: Two common approaches exist to develop emission factors for grid electricity generation, yielding slightly different values. The most common approach is to take a provincial average of the emissions resulting from electricity generation. In the Alberta case this emission factor is rather high given the amount of coal-fired electricity that is generated. The Alberta grid average emission factor is provided in the national inventory and is listed in Appendix 4: Default Data Tables. This number is updated annually, but is published 2 years after the fact (e.g. in 2008, the most recent data is from 2006).

Alternatively, emission factors can be developed considering not only current generators, but also new generators that would be the next to be built but that might be avoided or delayed due to projects that reduce the demand for electricity. In the regulated Alberta GHG Offset System, a combination of these two approaches has been taken, resulting in an emission factor that is lower than the provincial average – currently 0.65 tonnes CO2e/MWh.

Emissions are quantified through applying an appropriate emission factor to electricity consumption, using the standard emission factor equation.

Either emission factor can be used for quantification purposes, though a consistent approach should be used. Note, however, that where a project purchases electricity from a renewable / low emission energy source (e.g. through an electricity retailer), it may be appropriate to use a different electricity emission factor.

Once an emission factor is chosen, emissions from the source can be quantified using the equation below.

Equation 16: GHG emissions (kg CO2e) = $\sum_{\text{vehicle type or facility}}$ Electricity Consumed (kWh) * Electricity Grid Emission Factor (kg CO2e/kWh)

The same formula is used to quantify emissions in both the project and the baseline case. Total GHG emissions are equal to the sum of the emissions resulting from each vehicle type applicable in the case of vehicle efficiency / modal shift projects, or from transit facilities in the case of transit facility efficiency projects.

Methodologies to quantify the amount of electricity consumed are exactly the same as for the fuel combustion case in section 0 above. Fuel Combustion Volumes are simply replaced with Electricity

Consumption in the formulas, and the Fuel Combustion Emission Factor replaced with the Electricity Emission Factor.

Transmission Losses: Some electricity is lost during transmission from generators to final consumers in the form of heat, due to natural resistance in the wires. Transmission losses are typically estimated at 5% of the consumed amount of electricity. Where a project involves an increase in electricity consumption over the baseline, it is recommended that these losses be added to the amount of electricity consumption for project and baseline cases. Where the project involves a decrease in electricity consumption, consideration of transmission losses is optional since it would be conservative to ignore them.

Note, however, that where electricity bills / meter readings are used as the electricity consumption data source, bill amounts may already include a loss-adjustment. It is common for electric utilities to pass on the cost of this lost power to consumers, which then show up as an extra electricity consumption amount on a bill. Prior to calculating transmission losses, electricity bills should be reviewed to see if a loss factor has already been applied.

Electricity consumption for transit facility efficiency projects can be influenced by many factors outside the focus of a particular project. For instance, building occupancy / use levels can affect electricity usage in addition to equipment energy efficiency. Readers are referred to the International Performance Measurement and Verification Protocol (IPMVP) 2007 edition document for further details on how to address this issue.

6.6.6 FUEL EXTRACTION AND PRODUCTION

As described in section 6.6, emissions are quantified by multiplying relevant activity levels by appropriate emission factors. In the case of fuel extraction and production, these are:

Activity: all activities associated with the extraction and production / refining of fossil fuels or other feedstocks (such as biomass in the case of biodiesel blends) that are subsequently combusted in transit vehicles or used to heat/cool transit facilities.

The activity measured for the fuel extraction and production emission source is thus the combustion of fossil fuels (as well as alternative fuels such as biofuels).

Activity level: a measure of the amount of fuel combusted. This is typically in liters but can also be in other volumetric measures such as cubic meters (as is usually in the case of natural gas), or non-volumetric units such as mass (e.g. kg, tonnes, etc.) and energy (e.g. gigajoules, BTU, etc.).

Emissions are quantified through applying an appropriate emission factor to quantities of fuel consumed.

The following equation is used.

Equation 17: GHG emissions (kg CO2e) = $\sum_{\text{fuel type}}$ Fuel Combusted (L) X Fuel Extraction and Production Emission Factor (kg CO2e / L)

Methodologies to determine quantities of fuel combusted are identical to those presented in section 0. Note that little additional work is required here – the values for the Fuel Combustion parameter used to calculate emissions from the fuel combustion emission source would be used here to calculate the emissions resulting from fuel extraction and production. Only the emission factor used changes.

6.6.7 ACTIVITY DATA SOURCES

The table below summarizes common data sources for the main parameters used in the calculation methodology sections above.

Table 4: Activity Data Sources

Parameter	Vehicle Data Sources	Transit Facility Data Sources
Fuel consumption data (by fuel type)	• Fuel receipts, broken down by transportation fuel type; • Financial records of fuel expenditures[15]; • Direct measurement records, including official logs of vehicle fuel gauges or storage tanks.[16]	• Metered fuel consumption records, by fuel type • Heating bills
Electricity Consumption	• Direct measurement records, including official logs of vehicle electricity consumption	• Metered electricity consumption records • Electricity bills
VKM (by vehicle type)	• Odometer readings • Derived from transit route lengths or PKM • Canadian Vehicle Survey (average km travelled per vehicle class) • Transportation Canada Annual Report • Traffic counts • Edmonton Census Metropolitan Area (CMA) Household Travel Survey	
Personal Use Vehicle Types in Baseline	• Canadian Vehicle Survey • Vehicle registration records • Household Travel Surveys (e.g. CMA survey) • CMA vehicle registrations	n/a
Vehicle Occupancy	• Transit vehicles: estimates by transit operators • Personal use vehicles: Canadian Vehicle Survey?	N/a
Vehicle Efficiency (by vehicle type)	• Company fleet records that show data on fuel economy by	n/a

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[15] Average fuel price data is needed to convert expenditures into fuel consumption. This may be available from suppliers, or alternatively national/regional/local average fuel price data may be used.

[16] World Resources Institute (WRI), The Greenhouse Gas Protocol Initiative (2005). Calculating *CO2 Emissions from Mobile Sources Guidance Document v1.3*. http://www.ghgprotocol.org/calculation-tools/all-tools, accessed October 29, 2008.

	vehicle type, including original purchase records[17]; or • Vehicle manufacturer documentation showing fuel economy by vehicle type; or • UTEC, by vehicle class (included in Appendix 4); • Environment Canada's MOBILE6 model.	
Trip Length	• Transit route lengths (per route or combination of routes) • Estimated based on assumed typical commuting distance, for example in CUTA transit fact book	n/a
Breakdown of Mode of Transport	Statistics Canada Census of Population (provides numbers of people who drove, took transit, walked, biked for a number of jurisdictions – see Appendix)	

Consumption data for project estimation purposes will likely need to be estimated based on project specific performance improvement assumptions.

6.6.8 WORKING THROUGH MODAL SHIFT PROJECT VARIATIONS

Modal shift projects will fall into one of the following scenarios:

- Increased transit ridership on existing transit modes
- Existing transit ridership on new transit modes
- Increased transit ridership on new transit modes

A brief discussion of project and baseline considerations for the above scenarios follows.

Existing transit ridership on new transit modes

In this scenario, ridership levels do not change. Mode shift results from passengers moving from one mode to another *within* a transit system (e.g.shifting passengers from diesel buses to a new LRT service). It follows that VKM travelled in this situation should be relatively easy to quantify, as the transit routes affected by the project are likely known.

Increased transit ridership on existing transit modes

If the increased transit ridership can be accommodated on the existing transit fleet (i.e. no extra transit trips or additional vehicles are required), then no additional transit VKM are incurred as a result of the project.

Project fuel combustion emissions: In this scenario, the transit vehicles in the project and baseline cases are the same. In the project case, emissions from the transit modes included may be slightly higher than in the baseline case due to decreased fuel efficiency per VKM resulting from heavier loads (more passengers). If this decrease in fuel efficiency is not considered significant (e.g. less than 5%), then fuel

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[17] World Resources Institute (WRI), The Greenhouse Gas Protocol Initiative (2005). Calculating *CO2 Emissions from Mobile Sources Guidance Document v1.3*. http://www.ghgprotocol.org/calculation-tools/all-tools, accessed October 29, 2008.

combustion emissions from transit vehicles may be considered equivalent between the project and baseline case, and would not need to be quantified in either the project or the baseline case.

Baseline fuel combustion emissions: Fuel combustion emissions in the baseline case are generated by transit vehicles (these may in some cases be justified for exclusion, see project fuel combustion emissions above), and by the personal use vehicles that would have been driven by the new ridership the project generates. PKM travelled by the new ridership in the project case needs to be translated into VKM travelled in the baseline case by applying assumptions regarding the percentage of new ridership that drove in the baseline case and typical vehicle occupancy for personal use vehicles.

Increased transit ridership on new transit modes

Modal shift projects in this category will change emissions over baseline scenarios selected in two fundamental ways:

- By reducing emissions from transit vehicles through the migration to new and presumably lower emitting transit modes, and
- By increasing ridership, and therefore eliminating the emissions that would have been generated by the VKM travelled by personal use vehicles.

This is the most complex of the transit projects included in this guide, and special consideration needs to be taken to ensure functional equivalence is maintained between project and baseline scenarios.

In this scenario, inadvertently quantifying only one of the two benefits above will result in under-reporting the GHG benefits of the project. For example, if emissions are quantified due to the increase in ridership only (i.e. new PKM travelled in the project case due to the increase in ridership is translated to VKM in the baseline), then any emission reductions resulting from the change in transit mode for existing transit passengers would be missed.

Project emissions: In order to fully account for the mode changes, project emissions need to consider the TOTAL VKM travelled by both existing and new passengers in the new transit mode(s). The total VKM travelled needs to be converted to total project PKM travelled for use in baseline quantification.

Baseline emissions: Baseline emissions need to include emissions from existing transit vehicles used by existing transit passengers, AND emissions from the baseline travel modes used by those that will form the new transit ridership in the project case. In order to ensure functional equivalence, the total PKM travelled in the project must equal the total PKM travelled in the baseline.

Output from Step 6:

- Quantified emissions for the baseline.
- Quantified emissions for the project.
- Documentation of calculation methodology, including all assumptions.

6.7 STEP 7 – CALCULATE EMISSION REDUCTIONS

Baseline emissions quantified in Step 6 are subtracted from project emissions also quantified in Step 6 to obtain project emission reductions, as per the equation below, where a negative result indicates an emission reduction.

Equation 18: GHG reductions = GHG emissions $_{\text{project}}$ – GHG emissions $_{\text{baseline}}$

Calculating project and baseline emissions independently, and only calculating net reductions at the end, is a common feature of GHG quantifications, and is designed to avoid errors and double counting of benefits.

6.8 STEP 8 – DEVELOP MONITORING PLANS

In order to use the equations and methods described above, project and baseline data must be collected. To help ensure that the right types of data are collected, a monitoring plan should be prepared. A monitoring plan should be prepared in such a way that it can be easily used by project staff to determine what data needs to be collected, how it is to be collected, and by whom. Poor monitoring plans (along with poor data quality management plans) are a common cause of projects not being able to credibly report on achieved emission reductions. If key data is not collected due to the lack of a proper monitoring plan, it may not be possible to collect it after the fact!

Poor monitoring plans are a common cause of projects not being able to credibly report on achieved emission reductions.

A full monitoring plan should include details on the following, adapted from the ISO 14064-2 standard[18]:

a) Purpose of monitoring (overarching statement);

b) Types of data and information to be reported, including units of measure;

c) Data sources and monitoring methodologies (e.g. what steps / procedures should be followed by project staff to monitor each type of data, including direct measurement techniques, use of hard-copy accounting records, referencing published literature, etc, as appropriate).

d) Monitoring times and periods;

e) Monitoring roles and responsibilities;

f) GHG information management systems, including the location and retention of stored data.

Much of the above information can easily be presented in a tabular form, where each parameter requiring monitoring or collection would be described in a single row in the table. For instance, the following monitoring table template could be used:

GHG Source	Parameter	Units of Measure	Estimation / measurement approach	Frequency of monitoring	Responsible Party	Notes

Both project and baseline parameters would need to be listed, with parameters including not only directly monitored project data, such as fuel consumed, but any other data or assumptions needed. This other data could include data related to calculations, such as emission factors, vehicle occupancy data, etc., used to support any other decisions made during the quantification, such as selection of an appropriate baseline case. With regards to monitoring frequency, it should be noted that factors not directly

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[18] International Organization for Standardization (2006). ISO 14064-2:2006

measured will likely be monitored on a more infrequent basis, such as annually. Where multiple approaches are available for monitoring a particularly parameter, best practice would also dictate that some discussion should be provided regarding the relative merits of each option and reasons for selecting the final approach.

As part of data monitoring, thought should also be given to the system by which the data, once gathered, will be brought to a central location, stored, and analyzed. This system is referred to as a GHG information management system, and can range from simple to complex depending on the complexity of the project and available resources. Likely, this system will involve a combination of manual processes, such as transferring manual meter readings to a central location, and an electronic component, such as a spreadsheet or database, where recorded data is stored and processed. When designing this system, it is recommended that the advice from staff experienced in information management and technology be consulted to ensure that the system is practical, efficient, tailored to expected users' needs and skill level, and will serve to maintain data quality (see the next section below for more information on data quality).

Output from Step 8:

- Documented procedures to monitor selected quantification parameters.
- Post-project: data for monitored parameters collected adhering to data quality procedures.

6.9 STEP 9 – DEVELOP DATA QUALITY PROCEDURES

Even projects with large GHG emission reductions will not be able to credibly report on benefits unless there is general confidence in the quality of data used as a basis for the calculations. Risks to data quality exist in various forms, including: human error, equipment failure, improper meter calibration, corruption of electronic data, deliberate or accidental data tampering, and physical risks such as fire.

Often, preparing a detailed data quality management plan can seem overly onerous. However, where project goals include reporting on GHG emission reductions, it is critical that time be set aside up front to consider data quality management, since as with monitoring plans, poor data quality management plans are a common source of problems when reporting on emission reductions. In determining how rigorous the project's data quality management plan should be, consideration should be given to the planned use of the GHG quantification results and the needs of intended audiences – where a high degree of confidence in the results is required, more attention will need to be paid to data quality. Where this level of confidence is not required, then the recommendations provided below can be scaled accordingly. Additionally, a project proponent's organization or company may already be implementing quality management procedures in other areas – in these cases, existing systems should be leveraged as much as possible.

Where project goals include reporting on GHG emission reductions, it is critical that time be set aside up front to consider data quality management.

Data quality management plans typically address two related aspects:

- **Quality Control (QC)** – procedures designed to avoid errors or other reductions in data quality
- **Quality Assurance (QA)** – procedures designed to ensure that quality control procedures are being implemented as planned (essentially an internal audit function)

These aspects are addressed through some components of the plan, plus specific QC and QA procedures, as described below.

General Components of a Data Quality Management Plan

The following general components should be included in a data quality management plan:

- **Plan objective** – a clear statement of the purpose and goals of data quality management for the project

- **Responsible personnel** – all project personnel with a role to plan in data quality management, typically including those involved in data monitoring as well as others focused solely on QC or QA procedures, should be listed, including any minimum qualifications needed for specific roles / duties.

- **Data chain of custody** – the flow of data from the point of collection through to ultimate storage, analysis, and archiving, should be considered and clearly documented for each parameter to be monitored. This flow is referred to as the data chain of custody, and can often be easily illustrated for the entire project through the use of a simple flow diagram. Such a diagram would indicate the origin and endpoint for each type of data, plus the various places in between where the data is handled or otherwise manipulated.

Quality Control Procedures

Quality control procedures can include two general categories: parameter-specific procedures and general procedures.

Parameter-specific QC procedures

Parameter-specific quality control procedures would be determined by considering specific risks to data quality for each parameter being monitored. To identify risks, it is recommended that the data chain of custody be reviewed for each data type, and wherever data is being collected, transported, manipulated, or stored, ways in which the data might become corrupted or errors introduced should be considered. For instance, where fuel consumption data is collected by reading sales invoices and manually entered into a project database, sources of potential error would include reading from the wrong invoices, making unit errors (e.g. using liters instead of m3, or confusing gallons with liters) and data entry errors when transferring data from the invoices to the database. Naturally, those risks considered most significant, and those risks that impact the most important (largest) sources of emissions, should be given priority.

Such parameter-specific quality control procedures can include both manual procedures (e.g. requiring that all manual data entry be double-checked by a colleague, calibrating meters according to manufacturing specifications, etc.) and automated procedures built into the electronic portion of the GHG data information management system (e.g. forcing the user to enter only certain data types in a spreadsheet cell, or prompting the user to confirm the units that were used).

General QC procedures

General QC procedures that should be considered for inclusion in the data quality management plan include:

- **Periodic Data Checking / Analysis** – on a periodic basis, GHG calculations (or other analytical tests) could be performed on raw data and results analyzed to ensure that values fall in the expected range, or expected trends are observed.

- **Physical security** – the physical security of the data should be considered, and mitigation procedures implemented. Such physical risks include: fire, flood, natural disaster, power failure, theft, malicious tampering, etc. Physical security threats can also be managed through an effective data back-up and archiving procedure, discussed below.

- **Data Back-up and Archiving** – on a periodic basis, project data should be backed up by transferring a copy to a different storage system which would ideally be moved off site to reduce the risk of a single event compromising both current and backed-up data at the same time. On a longer time-frame, a more permanent data archive could also be established along similar lines.

Quality Assurance

Ideally, quality assurance procedures will be developed to periodically assess whether or not planned quality control procedures are being implemented. Such procedures could include examining records and logs, interviewing staff, observing procedures as they are implemented, etc. It is recommended that personnel involved in performing quality control procedures do not quality assure their own work, as an independent assessment will be more accurate and less biased.

A tabular format is also a useful means of organizing QA procedures, where for each quality control procedure being implemented, the associated QA procedure, frequency, and responsible party could be identified. Such a table could also be translated into a simple checklist that could be used by QA staff.

A process should be in place to address any quality control deficiencies as they are detected, including how issues are documented and how follow-up is conducted to ensure that corrective action is taken.

Best practices in quality assurance also recommend that a senior staff member be assigned overall responsibility and held accountable for all QA activities, and sign off on all QA checks / reports as they are periodically completed.

Output from Step 9:

- Documented data quality procedures.

7.0 DOCUMENTING AND REPORTING YOUR PROJECT

As with many aspects of quantifying GHG emission reductions for a project, the degree to which a project is rigorously documented and reported will depend on the intended uses for and audiences of the results. For instance, an emission reduction calculation prepared for an internal audience will likely require less documentation than something prepared to meet the requirements of a government funding program. Where independent 3rd party verification of emission reductions is desired, using an established standard such as ISO 14064-2 or the WRI GHG Protocol, one would expect that a high level of documentation would be required to ensure an efficient, least-cost audit. Additionally, fulsome documenting of methods, procedures and data will also make things easier should there be project staff turn-over and someone new be required to take charge of the GHG quantification.

The general rule of thumb, however, is that all decisions made and methods, procedures and assumptions used in preparing a GHG quantification should be transparently presented, in addition to providing final results. Ideally, these will be documented in a single report, prepared prior to commencement of the project to ensure that all monitoring and data quality procedures are in place prior to project start. Such a document is often referred to as a GHG Project Plan.

Additionally, as monitored data are collected and emission reduction calculations performed on a periodic basis, it is recommended that separate, concise emission reduction reports be created that detail the results of the calculations and any divergence from the methods outlined in the GHG Project Plan. Ideally, any specific claims being made, such as the amount of emission reductions for the current year, or that the calculations have been performed consistent with applicable program requirements, should be clearly stated.

For both GHG Project Plans and emission reduction reports, it is not necessary, however, to include every bit of data ever collected for the project. As long as such data has been recorded somewhere (e.g. the project's GHG information management system), and that a verifier or other reviewer could get easy access to that information if desired, then such information need not be included in a formal report. If in doubt, consider if excluding the information from a report would leave readers wondering about what approaches were taken, and why.

APPENDIX 1: TERMS AND DEFINITIONS

Term	Acronym	Definition
Activity Data		Data on the magnitude of human activity resulting in emissions or removals taking place during a given period of time[19]
Activity Level		A measure of activity data (e.g. L, kWh etc.)
Anaerobic		De-oxygenated
Anthropogenic GHGs		Greenhouse gases generated through man-made processes
Baseline Scenario		Hypothetical reference case that represents the conditions that would most likely have occurred in the absence of a GHG project. The baseline case runs for the same duration as the project
Carbon Dioxide Equivalent	CO_2e	The potency of a GHG expressed in terms to an equivalent amount of CO2
Electricity Grid		The infrastructure through which electricity is distributed in a region.
Emission Factor	EF	The average emission rate of a given GHG for a given source, relative to units of activity[20]
Emission Source		A physical unit or process releasing a GHG into the atmosphere
Functional Equivalence		A common basis for comparison between project and baseline scenarios in GHG quantification, used to ensure that project and baseline cases are measuring the same thing and offering equivalent levels of service (apples to apples comparison)
Global Warming Potential	GWP	CO2e over a 100 year period (e.g. GWP of methane is 25)
Greenhouse Gas	GHG	Atmospheric gas that traps solar energy reflected off or otherwise radiated by the earth in the earth's atmosphere, generally recognized as contributing to an overall warming climate.
GHG Efficiency Project (transit)		Project based on improvements to transit vehicles or facilities that reduce GHG emissions per level of service provided, irrespective of transit ridership levels
Greenhouse Gas Emission		Total amount (mass) of a GHG released into the atmosphere over a specific period of time
Greenhouse Gas Emission Reduction		The calculated decrease in GHG emissions between a baseline scenario and a GHG project
GHG Modal Shift Project (transit)		Projects that result in emissions reductions by shifting passengers from higher to lower emitting forms of transportation
Greenhouse Gas Project		A project implemented with the intent to generate GHG emission reductions, based on activities that alter conditions identified in a baseline scenario

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[19] Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories

[20] UNFCCC. http://unfccc.int/ghg_data/online_help/frequently_asked_questions/items/3826.php, accessed December 18, 2008.

Greenhouse Gas Report		Stand-alone document intended to communicate an organization or project's GHG-related information
Higher Heating Value	HHV	Also known as gross calorific value, the HHV is the amount of energy recovered from combusting a given quantity of fuel, assuming that combustion gases are returned to 25°C and the energy required to vapourize the water in the combustion gases (the latent heat of vapourization) is released as usable energy. Since vehicle combustion gases do not cool to 25°C prior to exiting the engine, the lower heating value is more appropriate for the case of vehicle fuel combustion.
Historic Baseline		Baseline case in which current conditions are projected into the future for the duration of the planned project
ISO 14064		International Standards Organization guidance document for project-based quantification
Lower Heating Value	LHV	Also known as net calorific value, the LHV is the amount of energy recovered from combusting a given quantity of fuel, assuming that combustion gases are returned to 150°C. In this case, more representative of vehicle combustion conditions than the HHV, water in the combustion gases remains a vapour when exhausted from the engine, and thus the latent heat of vapourization is not available to do useful work in the engine.
Methane	CH_4	GHG with a global warming potential of 25
Monitoring		Continuous or periodic assessment of GHG emissions and removals or other GHG-related data[21]
Joule	J	Unit of measure for energy
Light Rail Transit	LRT	
Nitrous Oxide	N_2O	A greenhouse gas with a GWP of 298
National Inventory Report	NIR	Annual report generated by Environment Canada containing detailed GHG emissions data at national, provincial, and sectoral levels submitted to the UNFCCC
Passenger-Kilometers	PKM	The number of kilometers traveled by a passenger
United Nations Framework Convention on Climate Change	UNFCCC	
Upstream emissions		Emissions generated due to the extraction and production of a resource (e.g. fossil fuels, electricity)
Quantification Standards		Approved methodologies that standardize ways of calculating GHG emissions to allow for accurate comparisons between different projects, companies, organizations and countries
Vehicle-Kilometers	VKM	The number of kilometers traveled by a vehicle
World Resources Institute	WRI	

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[21] ISO 14064

APPENDIX 2: VARIOUS APPROACHES TO PREDICTING RIDERSHIP

A number of approaches can be used to estimate ridership.

For existing routes, ridership may be measured by a number of different methodologies, including mechanical fareboxes, registering fareboxes, automatic passenger counters etc.

For new routes, the approach chosen may rely on the reason ridership quantification is required. For example, predicting ridership to determine revenue as a result of fare changes or for general budgetary planning purposes usually requires system-wide predictions. Predicting ridership (and consequently revenue) as a result of service changes can usually be isolated to route-level predictions. The implementation of sustainable transit projects will typically fall into the latter category (i.e. service changes) and as such the methods presented here are tailored to route-level (short run) prediction methods.[22]

Some of the more common route-level prediction methods for new routes include:

- Professional judgment
- Survey-based methods
- Cross-sectional models
- Time-series models[23]

Professional Judgment

Based on experience and local knowledge, this method is quite commonly used, especially when: there is a lack of faith in formal models; and/or when the development of formal models is not viable due to lack of data, and/or the expertise required to develop the models. The largest drawback of this approach is that the accuracy of predictions obtained using this method can not be verified or reproduced.

Survey-Based Methods

Passenger surveys are an important data-gathering tool. However, survey content and methodology will influence the quality of the data gathered.

In non-committal surveys, the responses of potential riders regarding how they would react to a service change are extrapolated to a larger ridership population. An adjustment factor, which can range from 0.05 to 0.50, is applied ridership figures to account for the “non-committal bias". This survey method is not generally recommended.[24]

Stated preference surveys are seen as a more viable statistical tool for evaluating responses to proposed transportation system changes. In this case, the surveys are based on rigorous design and data analysis.

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[22] Wilson, Nigel H.M. (2006). MIT Open Courseware. *Ridership Prediction*. http://ocw.mit.edu/NR/rdonlyres/Civil-and-Environmental-Engineering/1-258JSpring-2006/8E0C14C7-7FF8-41A4-9373-5434D2BE2545/0/lect10.pdf

[23] Wilson, Nigel H.M. (2006). MIT Open Courseware. *Ridership Prediction*. http://ocw.mit.edu/NR/rdonlyres/Civil-and-Environmental-Engineering/1-258JSpring-2006/8E0C14C7-7FF8-41A4-9373-5434D2BE2545/0/lect10.pdf

[24] Ibid.

The US Federal Transit Administration's slide dec, *Travel Forecasting for New Starts*[25], provides an overview of best practices in survey design. Issues discussed include questionnaire design (layout, readability, and avoidance of round-trip reporting) and the capture of key data items and trip characteristics (such as origin and destination purpose, access mode etc.).

Cross-Sectional Models

Cross-sectional models use route and demographic data to understand ridership. A number of methods can be used, including similar route methods and aggregate route regression models.

Time-series models

These models include elasticity methods, in which elasticity values are assigned to key variables such as fare and total travel time, and time series regression. Time series regression is quite rarely used due to its technically demanding nature and high data needs – furthermore the improvement of results offered relative to simpler methods is not proven.[26]

Other

Hiawatha Light Rail Transit Line (HLRT) operates an open boarding system Light Rail Transit Line (HLRT) from downtown Minneapolis to Fort Snelling. Obtaining ridership data is challenging due to the fact that there is no access to fare data. As such the agency relies on the following method to project ridership.

- "Personnel were interviewed from various areas of Metro Transit, including Revenue and Ridership, Service Development and the Police Department.
- Observations and counts of riders boarding HLRT trains were conducted by Program Evaluation and Audit in October of 2006.
- Additional observation and ridership count data was obtained from the Service Development saturation counts of ridership conducted in November 2006.
- Data from Program Evaluation and Audit, Service Development, and Revenue and Ridership were reviewed, compared and analyzed.
- Fare compliance devices were tested for timeliness, accuracy and reliability.
- Data collection and reporting practices of other light rail agencies were researched." [27]

A number of light rail agencies in the US have estimated ridership based on existing and projected travel patterns, combined with the experiences of operators of similar commuter rail services. Agencies that have used this method include *Salt Lake City Light Rail Project* in 1999, *Nashville Light Rail Project* in 1999, and *Rochester Light Rail Project* in 1998, as well as Sonoma-Marin.

The Sonoma-Marin plan was based on a number of key assumptions to allow for the definition of specific target markets:

- "Current congested conditions on the US 101 corridor during peak hours would persist indefinitely.
- Potential riders would be willing to drive up to 10 minutes from their homes to a station, or to take transit for the same distance.

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[25] US Federal Transit Administration (2007). *Travel Forecasting for New Starts.* http://www.fta.dot.gov/documents/Sessions_01-04.pdf, accessed November 17, 2008.

[26] Wilson, Nigel H.M. (2006). MIT Open Courseware. *Ridership Prediction*. http://ocw.mit.edu/NR/rdonlyres/Civil-and-Environmental-Engineering/1-258JSpring-2006/8E0C14C7-7FF8-41A4-9373-5434D2BE2545/0/lect10.pdf

[27] Metropolitan Council (May 2007). *Program Evaluation and Audit, Hiawatha Light Rail Transit Line (HLRT), Ridership Reporting and Fare Compliance*. http://councilmeetings.metc.state.mn.us/audit/2007/documents/2007-A09.pdf), accessed November 17, 2008.

- Upon arriving at their destination stations, riders would be willing to take either shuttle buses (provided by employers) or transit, or would walk to their workplaces.
- Riders would be willing to ride 10 minutes in a shuttle bus or transit, or walk about a half mile, from the stations to their workplaces.
- Peak ridership would account for 80 percent of total riders.
- Off-peak ridership would account for 20 percent of riders.
- San Francisco bound rail ridership (peak and off-peak) would comprise a 5 percent diversion of existing Golden Gate Transit (GGT) bus ridership."

The methodology used to predict ridership on the rail line was as follows:

1. Develop figures for the universe of potential riders by determining the number of home-based work trips within proposed transit area:
   a) Plot 3 circles around each proposed station: the first captures the area within a 10 minute drive to a station; the second captures the area within a 10 minute shuttle ride to work; and the third captures the area within a 0.5 mile walk to a station
   b) Review traffic analysis zone data available through Metropolitan Transportation Commission (MTC) to calculate number of home-based work trips from one zone to another
   c) Overlay two data sets to determine segment of population that satisfied assumptions (ie within assumed 10 minute drive proximity to proposed station etc.)
2. Determine Capture Rate (percentage of potential riders who might actually be attracted to rail service)
   a) Obtain and consolidate opinions of: other commuter rail operators offering similar service to understand their capture rate; ridership consultants with relevant experience; relevant staff at transpo commissions etc
   b) A number of variables considered, including concentration of jobs/major employers within a 5 mile radius of a station, an analysis of how difficult the general areas around the stations are to reach by car now due to recurring congestion etc.
3. Apply capture rate to universe of targeted work trips.[28]

APPENDIX 3: SUSTAINABLE TRANSIT INITIATIVES

The United States Department of Transportation's Federal Transit Administration maintains a clearinghouse of transit agency sustainable practices.[29]

Transit agencies featured include:

New York City Transit (MTA)
Massachusetts Bay Transportation Authority (MBTA)
Los Angeles County Metropolitan Transportation Authority
Dallas Area Rapid Transit
Sound Transit
Alameda-Contra Costa Transit (AC Transit)
Maryland Transit Administration (MTA)
Metro Transit

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[28] Wlibur Smith Associates. *Sonoma – Marin Rail Plan Chapter 5 (Ridership, Revenues and Operating Costs)*. http://www.co.marin.ca.us/depts/pw/main/rail/Chap5rail.pdf, accessed November 17, 2008.

[29] http://www.fta.dot.gov/planning/planning_environment_8524.html

APPENDIX 4: DEFAULT DATA TABLES

GLOBAL WARMING POTENTIALS

The table below provides the global warming potentials of the three major GHGs contributing to transportation emissions. Please note that these values are updated periodically by the IPCC.

Table 5: Global Warming Potentials[30]

Gas	Global Warming Potential
CO_2	1
CH_4	25
N_2O	298

EMISSION FACTORS

Vehicles

Emission factors by vehicle type are provided in the table below. CO_2, CH_4, and N_2O values are as reported in the 1990-2005 National Inventory Report. $CO_{2\,eq}$ in the table below represents total GHG emissions (i.e. emissions from CO_2, CH_4, and N_2O). The $CO_{2\,eq}$ values in the table are calculated using the global warming potentials in the table above. The $CO_{2\,eq}$ emission factors should be used in calculations.

In the event that GWPs for the three GHGs in the table above are updated, $CO_{2\,eq}$ values in the table below would need to be recalculated.

Table 6: Emission Factors for Energy Mobile Combustion Sources[31]

Vehicle Type	Engine Control Technology	CO_2	CH_4	N_2O	$CO_{2\,eq}$	Units
Gasoline Vehicles						
Light Duty Gasoline Vehicles (LDGVs)	Tier 1	2289	0.120	0.160	2339.68	g/L Fuel
	Tier 0	2289	0.320	0.660	2493.68	g/L Fuel
	Oxidation Catalyst	2289	0.520	0.200	2361.60	g/L Fuel
	Non-Catalytic Controlled	2289	0.460	0.028	2308.84	g/L Fuel
Light Duty Gasoline Trucks (LDGTs)	Tier 1	2289	0.130	0.250	2366.75	g/L Fuel
	Tier 0	2289	0.210	0.660	2490.93	g/L Fuel
	Oxidation Catalyst	2289	0.434	0.200	2359.45	g/L Fuel
	Non-Catalytic Controlled	2289	0.560	0.028	2311.34	g/L Fuel
Heavy-Duty Gasoline Vehicles (HDGVs)	Three-Way Catalyst	2289	0.680	0.200	2365.60	g/L Fuel
	Non-Catalyst	2289	0.290	0.047	2310.26	g/L Fuel

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[30] IPCC 4th Assessment Report 100-year timeframe

[31] Environment Canada (2008). NATIONAL INVENTORY REPORT: GREENHOUSE GAS SOURCES AND SINKS IN CANADA, 1990-2006 Annex 12: Emission Factors. http://www.ec.gc.ca/pdb/ghg/inventory_report/2006_report/a12_eng.cfm#ta12_7, accessed December 22, 2008.

	Controlled					
	Uncontrolled	2289	0.490	0.084	2326.28	g/L Fuel
Motorcycles	Non-Catalytic Controlled	2289	1.400	0.045	2337.41	g/L Fuel
	Uncontrolled	2289	2.300	0.048	2360.80	g/L Fuel
Diesel Vehicles						
Light Duty Diesel Vehicle (LDDVs)	Advance Control	2663	0.051	0.220	2729.84	g/L Fuel
	Moderate Control	2663	0.068	0.210	2727.28	g/L Fuel
	Uncontrolled	2663	0.100	0.160	2713.18	g/L Fuel
Light-Duty Diesel Trucks (LDDTs)	Advance Control	2663	0.068	0.220	2730.26	g/L Fuel
	Moderate Control	2663	0.068	0.210	2727.28	g/L Fuel
	Uncontrolled	2663	0.085	0.160	2712.81	g/L Fuel
Heavy-Duty Diesel Vehicles (HDDV)	Advance Control	2663	0.120	0.082	2690.44	g/L Fuel
	Moderate Control	2663	0.140	0.082	2690.94	g/L Fuel
	Uncontrolled	2663	0.150	0.075	2689.10	g/L Fuel
Natural Gas Vehicles						
Natural Gas Vehicles		1.890	9×10-3	6×10-5	2.13	g/m3 Fuel
Propane Vehicles						
Propane Vehicles		1510	0.640	0.028	1534.34	g/L Fuel
Off-Road Vehicles						
Off-Road	Off-Road Gasoline	2289	2.700	0.050	2371.40	g/L Fuel
	Off-Road Diesel	2663	0.150	1.100	2994.55	g/L Fuel
Railways						
Railways	Diesel Train	2663	0.150	1.100	2994.55	g/L Fuel

The national inventory accounts for the penetration of various engine control technologies based on the availability of technologies per model year of vehicle. In other words, the model year of the vehicle in question determines which engine control technology should be used. In the table below, tier 1 represents the most recent engine control technology, followed by tier 0, and so on.

The penetration of various engine control technologies for light duty gasoline vehicles and trucks is captured in the figure below.

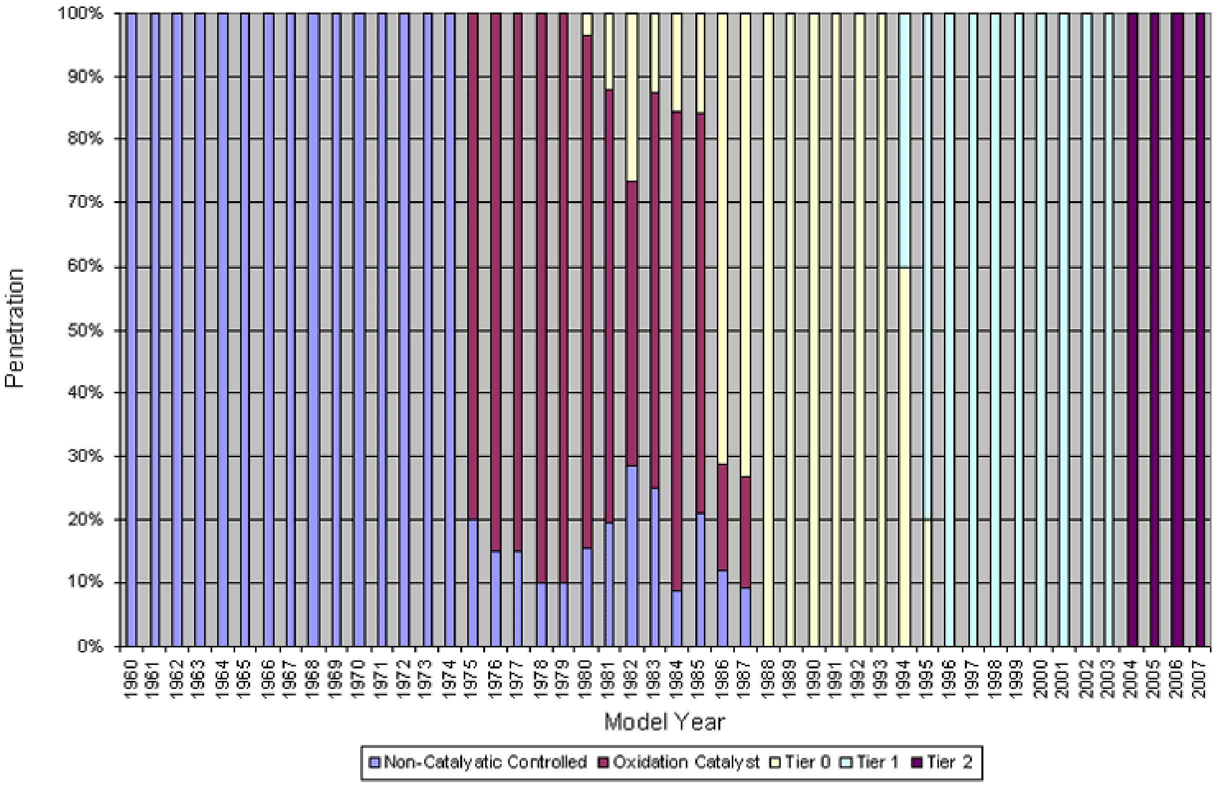

Figure A2-2: Technology Penetration for Light-Duty Gasoline Vehicles and Trucks

Figure 5: Engine Control Technology Penetration for Light-Duty Gasoline Vehicles and Trucks[32]

The use of various engine control technologies for heavy duty gasoline vehicles, diesel vehicles, and motorcycles is included in the table below.

Table 7: Technology Penetration for HDGVs, HDDVs, LDDVs, LDDTs, and MCs[33]

Control Technology	Model years
Heavy-Duty Gasoline Vehicles (HDGVs)	
Uncontrolled	1960-1984
Non-Catalytic Controlled	1985-1995
Three-Way Catalyst	1996-2007
Heavy-Duty Diesel Vehicles (HDDVs)	
Uncontrolled	1960-1982
Moderate Control	1983-1995
Advanced Controls	1996-2007
Light-Duty Diesel Vehicles & Trucks (LDDVs & LDDTs)	
Uncontrolled	1960-1982
Moderate Controls	1983-1995

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[32] Environment Canada. *NATIONAL INVENTORY REPORT: GREENHOUSE GAS SOURCES AND SINKS IN CANADA, 1990-2006*. http://www.ec.gc.ca/pdb/ghg/inventory_report/2006_report/images/fa2_2_l_eng.gif, accessed December 22, 2008.

Advanced Controls	1996-2003
Tier 2	2004-2007
Motorcycles (MCs)	
Uncontrolled	1960-1995
Non-Catalytic Controlled	1996-2007

Biofuels

The national inventory (the source for the tables above) contains limited information on emission factors for biofuels. A CO_2 value is listed for ethanol in the inventory; however it appears to be only for E100. Assuming that the ethanol is produced from natural renewable materials (such as corn) that would have decomposed anyway, the CO2 listed in the inventory would be considered GHG neutral and would not need to be reported. For this reason the NIR is not listed as a source for emission factors for biofuels.

Instead, readers are referred to GHGenius[34] for biofuels emission factors. GHGenius is a lifecyle assessment model for transportation fuels developed for Natural Resources Canada. It provides a much more comprehensive source for biofuels and takes into consideration upstream emissions, an important consideration for biofuels. Note however that if GHGenius is used as a source for biofuels emission factors, then in order to be consistent, it should also be used as the source for emission factors for the other fuels used in your project.

Heating Fuels

The table below provides emission factors for heating fuels, to be used to quantify fuel combustion emissions for transit facilities.

Table 8: Emission Factors for Refined Petroleum Products[35]

Source	Emission Factors (g/L)		
	CO2	CH4	N2O
Light Fuel Oil			
Electric Utilities	2830	0.18	0.031
Industrial	2830	0.006	0.031
Producer Consumption	2830	0.006	0.031
Residential	2830	0.026	0.006
Forestry, Construction, Public Administration, and Commercial/Institutional	2830	0.026	0.031
Heavy Fuel Oil			
Electric Utilities	3080	0.034	0.064
Industrial	3080	0.12	0.064
Producer Consumption	3080	0.12	0.064
Residential, Forestry, Construction, Public Administration, and Commercial/Institutional	3080	0.057	0.064
Diesel	2730	0.133	0.4

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[34] GHGenius. http://www.ghgenius.ca/.

[35] Environment Canada (2008). NATIONAL INVENTORY REPORT, 1990-2005: GREENHOUSE GAS SOURCES AND SINKS IN CANADA, ANNEX 12: EMISSION FACTORS. Table A12-2, http://www.ec.gc.ca/pdb/ghg/inventory_report/2005_report/a12_eng.cfm#ta12_7, accessed October 29, 2008

Electricity

The following table lists 2 potential emission factors for electricity generation in Alberta.

Table 9: Electricity generation emission factors

	Emission Factor	Source
Alberta grid electricity generation, average of existing generators.	0.861 Tonne CO2 eq / MWh	Environment Canada, Canada's Greenhouse Gas Inventory (1990-2004)
Alberta grid electricity generation, conservative combined margin factor	0.65 tonnes CO2e/MWh	Alberta GHG Offset System

VEHICLE FUEL EFFICIENCIES

The table below provides fuel efficiencies by vehicle type, as compiled by Transport Canada's Urban Transportation Emission Calculator (UTEC). UTEC's source for gasoline and diesel vehicles is Environment Canada's MOBILE6.2C forecasts, and for alternative energy vehicles is a report prepared for the National Climate Change Process, *Alternative and Future Fuels and Energy Sources for Road Vehicles*, Edwards, W., Dunlop, R., and Duo, W. Levelton Engineering Ltd. July 12, 1999.

Table 10: Fuel Efficiencies by Vehicle Type[36]

Year	Vehicle Type	G	D	P	NG	E10	E85	M85	HYB	EB	EFC
2006	LDPV-A	9.8	7.3	12.1	8.1	10	12.5	15.1	6.8	89.2	10.7
2006	LDPV-T	12.6	10.6	15.6	10.4	12.9	16	19.4	8.8	114.6	13.8
2006	LDCV	16.4	13.5	20.2	13.6	16.8	20.9	25.3	10.1	149.2	17.9
2006	HDCV	25.6	30.6	53.3	61.5	0	0	0	0	0	0
2006	BUS	36.8	55.2	97.2	112.3	0	0	0	32.5	0	94.8
2006	TB	0	0	0	0	0	0	0	0	0	0
2006	LR-E	0	0	0	0	0	0	0	0	0	0
2006	LR-D	0	0	0	0	0	0	0	0	0	0
2006	HR	0	0	0	0	0	0	0	0	0	0
2011	LDPV-A	9.8	7.3	12.1	8.1	10	12.5	15.1	6.8	89.2	10.7
2011	LDPV-T	12.7	10.6	15.7	10.5	13	16.2	19.6	8.8	115.5	13.9
2011	LDCV	16.4	13.6	20.2	13.6	16.8	20.9	25.3	10.2	149.2	17.9
2011	HDCV	25.2	29.8	51.9	59.9	0	0	0	0	0	0
2011	BUS	36.7	54.7	96.4	111.3	0	0	0	32.2	0	93.9
2011	TB	0	0	0	0	0	0	0	0	0	0
2011	LR-E	0	0	0	0	0	0	0	0	0	0
2011	LR-D	0	0	0	0	0	0	0	0	0	0
2011	HR	0	0	0	0	0	0	0	0	0	0
2016	LDPV-A	9.8	7.3	12.1	8.1	10	12.5	15.1	6.8	89.2	10.7
2016	LDPV-T	12.7	10.6	15.7	10.5	13	16.2	19.6	8.8	115.5	13.9
2016	LDCV	16.5	13.7	20.4	13.6	16.9	21	25.5	10.2	150.1	18
2016	HDCV	24.9	29	50.5	58.3	0	0	0	0	0	0

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[36] Transport Canada. *UTEC Fuel Efficiency*. http://www.tc.gc.ca/programs/environment/UTEC/FuelEfficiency.aspx, accessed December 18, 2008.

2016	BUS	36.7	54.3	95.7	110.5	0	0	0	31.9	0	93.2
2016	TB	0	0	0	0	0	0	0	0	0	0
2016	LR-E	0	0	0	0	0	0	0	0	0	0
2016	LR-D	0	0	0	0	0	0	0	0	0	0
2016	HR	0	0	0	0	0	0	0	0	0	0
2021	LDPV-A	9.8	7.3	12.1	8.1	10	12.5	15.1	6.8	89.2	10.7
2021	LDPV-T	12.7	10.6	15.7	10.5	13	16.2	19.6	8.8	115.5	13.9
2021	LDCV	16.6	13.8	20.5	13.7	17	21.1	25.6	10.3	151	18.1
2021	HDCV	24.5	27.9	48.6	56.1	0	0	0	0	0	0
2021	BUS	36.6	53.5	94.3	108.9	0	0	0	31.5	0	91.9
2021	TB	0	0	0	0	0	0	0	0	0	0
2021	LR-E	0	0	0	0	0	0	0	0	0	0
2021	LR-D	0	0	0	0	0	0	0	0	0	0
2021	HR	0	0	0	0	0	0	0	0	0	0
2026	LDPV-A	9.8	7.3	12.1	8.1	10	12.5	15.1	6.8	89.2	10.7
2026	LDPV-T	12.7	10.6	15.7	10.5	13	16.2	19.6	8.8	115.5	13.9
2026	LDCV	16.6	13.8	20.5	13.7	17	21.1	25.6	10.3	151	18.1
2026	HDCV	24.1	26.2	45.6	52.7	0	0	0	0	0	0
2026	BUS	36.7	53.5	94.3	108.9	0	0	0	31.5	0	91.9
2026	TB	0	0	0	0	0	0	0	0	0	0
2026	LR-E	0	0	0	0	0	0	0	0	0	0
2026	LR-D	0	0	0	0	0	0	0	0	0	0
2026	HR	0	0	0	0	0	0	0	0	0	0
2031	LDPV-A	9.8	7.3	12.1	8.1	10	12.5	15.1	6.8	89.2	10.7
2031	LDPV-T	12.7	10.6	15.7	10.5	13	16.2	19.6	8.8	115.5	13.9
2031	LDCV	16.6	13.8	20.5	13.7	17	21.1	25.6	10.3	151	18.1
2031	HDCV	23.7	24.3	42.3	48.9	0	0	0	0	0	0
2031	BUS	36.7	53.4	94.1	108.7	0	0	0	31.4	0	91.7
2031	TB	0	0	0	0	0	0	0	0	0	0
2031	LR-E	0	0	0	0	0	0	0	0	0	0
2031	LR-D	0	0	0	0	0	0	0	0	0	0
2031	HR	0	0	0	0	0	0	0	0	0	0

Fuel efficiencies will vary based on a number of factors such as driving speed, road conditions, etc. The following table provides fuel efficiency adjustment factors to account for different driving speeds.

Table 11: Fuel Efficiency Adjustment Factors by Average Speed[37]

Min Speed (km/h)	Max Speed (km/h)	Adj Factor
0	11.99	2.8
12	19.99	1.8
20	27.99	1.4
28	35.99	1.2
36	43.99	1.1
44	99.99	1

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[37] Transport Canada. *UTEC Fuel Efficiency*. http://www.tc.gc.ca/programs/environment/UTEC/FuelEfficiency.aspx, accessed December 18, 2008.

100	1000	1.1

HEATING VALUES

Heating values are used to convert volumes between fuel types for fuel switching projects (see section 6.6.4.2).

Heating values are either expressed as Higher Heating Values (HHV), or Lower Heating Values (LHV).

In the HHV case, it is assumed that combustion gases are returned to 25 deg C, and the latent heat of vapourization (the energy required to do a phase shift from liquid to gas, which is given off by a substance as it is cooled from a gas to a liquid) is recovered by the application.

Since the ration of LHV to HHV is different for different fuels, use of HHV vs. LHV will actually make a difference (though probably a minor one). The energy present in the fuel that would be used to vapourize water would not be recovered in a vehicle, so this energy can be thought of as lost. That means that only the remaining energy or LHV will actually go into powering the vehicle. As such, a list of LHVs is provided in the table below.

Table 12: Lower Heating Value[38]

Fuel	LHV	Unit
Crude Oil	38.5	MJ/L
Gasoline	32.2	MJ/L
Diesel	35.6	MJ/L
Ethanol	21.2	MJ/L
Biodiesel	33	MJ/L
Hydrogen @ 35MPa (HHV)	2.7	MJ/L
Natural Gas @ STP	37	MJ/m3
CNG @ 20MPa	9.288	MJ/L
LPG@1.5MPa	23.3	MJ/L
Methanol	16.71	MJ/L

LIFESPAN OF TRANSIT VEHICLES

The following table provides the typical lifespan of transit vehicles. Lifespans in the table below should be used for transit project GHG quantification.

Table 13: Average Lifespan of Transit Vehicles

Transit Vehicle	Average Lifespan
Community Bus	7 to 10 years*
40' Diesel Bus	18 years
40' Hybrid Bus	18 years
Trolley bus	18 years
Articulated bus	18 years
Light Rail Vehicle (LRV)	35 years

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[38] MIT. *Units & Conversions Fact Sheet.* http://web.mit.edu/mit_energy, accessed December 22, 2008.

* It is difficult to estimate the average lifespan of a community bus due to range of choices in the types of vehicles that are typically used.

LABOUR FORCE BY MODE OF TRANSPORTATION

Statistics Canada's Census of the Population can be used to gain some insight into how the employed labour force commutes to work.

Table 14: Employed labour force(1) by mode of transportation, both sexes, 2006 counts, for Canada, provinces and territories, and census metropolitan areas and census agglomerations of residence – 20% sample data

	Mode of transportation							
				Sustainable transportation[4]				
Place of residence[3]	**Total**	**Car, truck or van as driver**	**Car, truck or van as passenger**	**Total**	**Public transit**	**Walked**	**Bicycle**	**Other**
Canada	**14,714,260**	**10,644,325**	**1,133,150**	**2,757,530**	**1,622,725**	**939,290**	**195,515**	**179,250**
Alberta	**1,686,540**	**1,253,085**	**133,395**	**274,505**	**155,480**	**99,725**	**19,300**	**25,555**
Brooks, CA	11,280	8,785	1,600	780	15	640	120	110
Calgary, CMA	584,505	403,820	43,965	130,690	91,370	31,755	7,565	6,035
Camrose, CA	7,445	5,900	650	695	30	580	85	200
Canmore, CA	6,880	5,010	420	1,305	40	940	320	145
Cold Lake, CA	6,690	5,185	860	580	25	440	110	60
Edmonton, CMA	546,070	409,650	42,740	87,040	52,990	27,815	6,235	6,630
Grande Prairie, CA	39,575	32,830	3,335	2,940	665	2,070	200	475
Lethbridge, CA	46,115	37,800	3,515	4,255	1,000	2,600	660	540
Lloydminster, CA	14,775	12,380	1,300	910	60	755	95	190
Lloydminster (Alberta part)	8,655	7,350	680	530	35	430	65	90
Lloydminster (Saskatchewan part)	6,125	5,025	620	375	20	325	35	95
Medicine Hat, CA	35,090	29,525	2,670	2,345	675	1,385	285	545
Okotoks, CA	9,015	7,460	710	720	260	370	90	120
Red Deer, CA	46,170	36,525	4,115	4,820	1,730	2,485	600	710
Wetaskiwin, CA	5,420	4,215	585	560	30	450	75	65
Wood Buffalo, CA	31,870	16,660	4,480	6,250	4,725	1,465	55	4,480

Notes:

1. Persons who, during the week (Sunday to Saturday) prior to Census Day (May 16, 2006):

   (a) did any work at all for pay or in self-employment or without pay in a family farm, business or professional practice

   (b) were absent from their job or business, with or without pay, for the entire week because of a vacation, an illness, a labour dispute at their place of work, or any other reasons.

2. Place of work data are not available for percent distribution (1996) and percentage change (1996 to 2006).

3. Place of residence: applies to the employed labour force with either a usual place of work or with no fixed workplace address.

4. Sustainable transportation includes public transit, walking and cycling.

Sources : Statistics Canada, censuses of population, 1996 to 2006.
http://www12.statcan.ca/english/census06/data/highlights/POW/Table603.cfm?SR=1.

ALBERTA SALES OF REFINED PETROLEUM PRODUCTS

Petroleum sales data may be a reference source for some baseline scenarios looking to quantify fuel use.

Table 15: Domestic sales of refined petroleum products (Alberta)[39]

Annual	All refined petroleum products	Motor Gasoline	Diesel Fuel Oil
1989	10,129.80	4,614.30	2,809.80
1990	10,157.90	4,603.10	2,800.50
1991	9,454.80	4,203.10	2,589.70
1992	9,418.60	4,257.90	2,506.40
1993	9,926.80	4,251.70	2,764.70
1994	10,721.50	4,428.10	3,200.20
1995	11,000.30	4,399.90	3,372.40
1996	11,898.50	4,490.30	3,648.50
1997	12,985.10	4,703.00	4,192.30
1998	12,948.00	4,906.80	4,274.60
1999	12,962.20	4,970.50	4,318.60
2000	13,617.20	4,953.80	4,684.30
2001	14,152.90	5,289.70	4,804.20
2002	13,428.10	5,302.90	4,448.60
2003	14,251.20	5,187.60	4,925.60
2004	15,269.00	5,320.70	5,257.70
2005	15,781.60	5,383.00	5,604.80
2006	16,595.20	5,593.20	6,218.00
Monthly			
2007			
January	1,457.00	452.90	607.8
February	1,396.00	425.10	572.1
March	1,436.10	476.60	566.8
April	1,198.80	445.20	437.6
May	1,460.20	504.40	534.6
June	1,499.10	495.80	527.8
July	1,576.10	546.90	562.8
August	1,627.80	519.20	627.6
September	1,587.20	475.60	628.8
October	1,667.40	492.30	673.7
November	1,561.00	474.10	609.7
December	1,431.60	486.70	549

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[39] Statistics Canada (second quarter 2008). Energy Statistics Handbook. Catalogue No. 57-601-X. Tables 5.4-1, 5.4-2, 5.4-4

Total	17,898.20	5,794.80	6,898.30
Monthly			
2008			
January	1,568.40	452.50	622
February	1,495.90	445.90	660.5
March	1,576.80	473.10	576.6
April	1,348.50	456.10	512.5
May	1,505.20	527.90	559.9
June	1,529.00	503.10	543.5
Cumulative			
2008	9,023.80	2,858.60	3,474.90
2007	8,447.20	2,800.00	3,246.70

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