**Guidance Document**

# Vacation Travel GHG Calculator

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# Guidance Document for Manitoba Green Registry: Vacation Travel GHG Calculator



## Importance of this Calculator

Each year, many Manitobans travel to holiday destinations, often going thousands of kilometres to their vacation spots. Vacation travel often includes air travel, but trips are also taken by train, car, bus, and other modes of transportation. The **Manitoba Vacation Travel GHG Calculator** allows individual user to estimate the GHG emissions resulting from their vacation travel. The calculator provides a GHG emissions estimate that accounts for the total distance travelled from home to the vacation destination accounting for the mode of travel and the number of trips taken each year.

The calculator uses a web interface with a form for the user to provide information found at www.greenregistry.org. Users of the calculator can take the carbon footprint estimate provided by the calculator as a baseline of GHG emissions from their vacation choices. This baseline may then be used to compare the carbon footprints of different travel options when making future travel decisions. Users can also use the GHG emissions calculation for their trip in order to purchase offsets for the resulting GHG emissions.

# Scope of Activity and Emissions

The **Manitoba Vacation Travel GHG Calculator** can be used to estimate the GHG emissions from any number of vacation travel events that might take place over one year. The calculator is able to measure GHG emissions from domestic and international trips using four different modes of travel, namely: airplane, train, bus, and personal passenger vehicle. Carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) are the three types of GHGs that could be emitted from the various modes of travel and these are all included in the calculations. In order to present a single metric for GHG emissions from vacation travel the three GHGs are converted to their carbon dioxide equivalence ($CO_2e$) and the total GHG emissions are presented as $CO_2e$.

# Required User Inputs

The **Manitoba Vacation Travel GHG Calculator** has been designed to be as user friendly as possible requiring minimal data inputs. The user inputs that are required to generate estimates of GHG emissions associated with personal travel are outlined below:

**Input 1:** The type of vehicle or mode of travel. Options include airplane, bus, train, or personal passenger vehicle.

**Input 1(a):** The personal passenger vehicle category includes options for selecting the specific make, model and year of vehicle and the engine size, transmission type and fuel. These are provided in the form of a drop-down menu.

**Input 1(b):** The airplane category includes options for selecting the size or type of airplane from a drop-down menu.

**Input 2:** Distance from departure to arrival locations. Providing departure and arrival locations allows the calculator to determining the distance travelled for each trip. This can be provided by specifying the city and the country (e.g. Winnipeg, Canada) or a full address (e.g. 25 Main St. Brandon, MB) of the departure and arrival points. The calculator then uses its mapping application to estimate the total distance travelled.

**Input 3:** Number of passengers in the vehicle. GHG emissions are estimated for each person going on the trip. In the case of travel by personal passenger vehicle the GHG emissions total for the trip are divided by the number of passengers. Any whole number is an acceptable input.

**Input 4:** Round trip. The calculator allows the user to identify a one-way trip using one mode of transportation and a one-way trip home again using an alternate mode. This allows the calculator to be more precise when the trip is of a more complicated nature and the travel plans include multiple modes of transportation.

## Underlying Method and Data Sources

The **Manitoba Vacation Travel GHG Calculator** includes GHG emission calculations for four different forms of travel, namely; airplane, bus, train, and personal passenger vehicle. Calculating GHG emissions involves the multiplication of activity (i.e., passenger kilometres traveled or PKT) by the GHG emission intensity for that activity. Although the overarching approach to calculating the GHG emissions is the same, each mode relies on different analytical steps and data sources.

### Estimating Activity

For all forms of travel, the first step is finding the passenger kilometres traveled. The precise measure of distance traveled depends upon the mode of travel and the geographical location of the origin and destination. To get the distance traveled as easily and accurately as possible, the calculator relies on a web-based mapping application.[1] This allows the user to enter their departure and destination addresses and let the mapping application determine the total distance of the trip.

Passenger kilometres traveled (PKT) by airplane is based on the linear function of the online mapping application. In this case the mapping application calculates the distance between the origin and destination points based on the great circle formula (this is the most direct route accounting for the curvature of the earth). A similar approach is used for rail, with the assumption that rail transportation infrastructure follows closely the most direct route between major centres.

To generate estimates of PKT for bus and personal passenger vehicle modes, a different functionality of the mapping application is used. Rather than relying on the great circle distance, the mapping application traces the road network from point of departure to point of destination, selecting the shortest distance along the road network.

### Estimating Emissions

Central to the estimation of GHG emissions associated with personal travel is the use of GHG emissions intensities provided on a unit of $CO_2$e per PKT basis. GHG emissions intensities for PKT are especially relevant for modes which carry multiple passengers, such as airplanes, trains, and buses. Otherwise, GHG emissions associated with vehicle movements would be allocated only to one passenger, whereas they should be distributed proportionally to all passengers. The process to generate PKT GHG emissions intensities differs for each mode and draws upon a range of data sources and methodologies.

The approach for estimating GHG emissions from vacation travel is formulized as:

[1] http://maps.google.com/

**Equation 1:** *Estimating GHG emissions from vacation travel:*

$$\mathbf{VacationTravel}_{\text{Emissions}} = \sum\nolimits_{\text{alltravel}} \left\{ \mathbf{PKT}_{\text{Mode}} * \mathbf{EmInt}_{\text{Mode}} \right\}$$

Where

$\mathbf{VacationTravel}_{\mathbf{Emissions}}$ = Total GHG emissions from vacation travel per year
$\mathbf{PKT}_{\mathbf{Mode}}$ = Total passenger kilometres travelled by mode per year
$\mathbf{EmInt}_{\mathbf{Mode}}$ = GHG emission intensity by mode and type of trip (Appendix A)

The mode-specific methods used to establish each term of equation 1 is provided in Appendix A.

## Using the Calculator

The Vacation Travel Calculator is extremely flexible and allows users to measure GHG emissions from their specific types of vacation travel and number of trips per year. This is an important tool for measuring the contribution your vacation choices make to your carbon footprint. Understanding the GHG emissions arising from the vacation trips we take is a valuable step in addressing climate change in Manitoba. GHG emissions from vacation travel can be a large part of our individual carbon footprint depending upon the types of vacation we take and the modes of transportation we choose.

The **Manitoba Vacation Travel GHG Calculator** produces a fairly accurate estimate of GHG emissions from vacation trips because of the variety of travel options it can accommodate and the accuracy of GHG emissions intensity for the different types of vehicles. This GHG emissions measurement from individual vacations is the starting point for planning how to reduce GHG emissions. The calculator links the user to incentive programs and recommended actions for reducing travel-related GHG emissions. Users can also select the option to offset the GHG emissions resulting from their vacation travel.

# Appendix A. GHG Emission Factors for Vacation Travel

**Table 1. GHG Emission Intensities for Vacation Travel by Personal Passenger Vehicle**

| Type of Vehicle | Fuel consumption (L/100 km) City | Highway | Blended | Emission Intensity $CO_2e$ (tonnes/km) Gas | Diesel |
|---|---|---|---|---|---|
| Sub-compact (Honda Civic) | 8.2 | 5.7 | 6.8 | 0.0001632 | 0.0001836 |
| Compact (Mazda 3) | 9.2 | 6.7 | 7.8 | 0.0001872 | 0.0002106 |
| Mid-size (Chevrolet Malibu) | 12.2 | 7.8 | 9.8 | 0.0002352 | 0.0002646 |
| Full-size (Ford Crown Victoria) | 13.4 | 8.6 | 10.8 | 0.0002592 | 0.0002916 |
| Station Wagon (Volkswagen Passat Wagon) | 12.7 | 8.3 | 10.3 | 0.0002472 | 0.0002781 |
| Pickup Truck (Dodge Dakota) | 14.4 | 9.8 | 11.9 | 0.0002856 | 0.0003213 |
| Special Purpose (SUV) (Cadillac Escalade) | 17.7 | 10.8 | 13.9 | 0.0003336 | 0.0003753 |
| Minivan (Chrysler Town & Country) | 12.2 | 7.9 | 9.8 | 0.0002352 | 0.0002646 |
| Large Van (GMC Savana) | 15.4 | 11.2 | 13.1 | 0.0003144 | 0.0003537 |

*Source: Natural Resources Canada Vehicle Fuel Efficiency Guide 2009*

Table 1 includes representative GHG emission intensities for common vehicle classes. These intensities may not precisely reflect the intensities of the vehicles actually used. For a precise calculation of GHG emissions from personal passenger vehicles identify the specific vehicles used in the Natural Resources Canada Vehicle Fuel Efficiency Guide 2009. The fuel consumption ratings (in L/100 km) found in the guide should be multiplied by a GHG emission factor of 2.4 kg/L for gasoline and 2.7 kg/L for diesel.

**Table 2. GHG Emission Intensities for Vacation Travel by Mode and Type of Trip**

| Mode | Emission Intensity $CO_2e$ (tonnes/PKT) |
|---|---|
| Bus | 0.00007137 |
| Train | 0.0001902 |
| Airplane: | |
| Short haul (under 500 km) small jet (e.g., Dash 8), all seating | 0.00014 |
| Medium haul (500 to 1600 km) regional jet (e.g. CRJ-2), economy seating | 0.00012 |
| Medium haul (500 to 1600 km) regional jet (e.g. CRJ-2), business class | 0.00017 |
| Medium haul (500 to 1600 km) turbo prop (e.g., NexGen Q400), all seating | 0.00011 |
| Long haul (over 1600 km) large jet (e.g., Boeing 767), economy seating | 0.00011 |
| Long haul (over 1600 km) large jet (e.g., Boeing 767),business class seating | 0.00021 |

*Source: GHG emission intensity estimates shown here are estimated using the methodology described below using fuel GHG emission estimates from Statistics Canada Energy Statistics Handbook 2008, and EMEP/CORINAIR Emission Inventory Guidebook (EIG)*

## *Estimating Distance Traveled and GHG Emission Factors*

The first step in estimating the GHG emission associated with vacation travel is establishing the passenger kilometres traveled (PKT) associated with travel by mode. The precise measure of distance traveled depends upon the mode of travel and the geographical location of the origin and destination of the trip.

To determine the distance traveled the calculator relies on a mapping application such as the web-based Google Maps application[2] or similar tool using departure and destination address for all trips:

**Airplane**

- PKT by airplane are based on the great circle distance function calculating the distance between the origin and destination points (this is the most direct route after accounting for the curvature of the earth).

  **Great Circle Distance is calculated as:**
  Earth Radius = 6371;
  lat_delta = lat1 - lat2;
  long_delta = long1 - long2;
  a = Math.sin( lat_delta/2 ) * Math.sin( lat_delta/2 ) + Math.cos( lat1 ) * Math.cos( lat2 ) * Math.sin( long_delta/2 ) * Math.sin( long_delta/2 );
  c = 2 * Math.atan2( Math.sqrt( a ), Math.sqrt( 1-a ) );
  distance = EARTH_RADIUS * c;
  Source: http://en.wikipedia.org/wiki/Great-circle_distance

- Factors that influences the distance of a flight include re-routes, head winds, refuelling stops, or other factors that can take a plane off of its optimal flight path. Therefore following the approach used by the International Civil Aviation Organization (ICAO), correction factors are applied to the estimated PKT based on the distance of each flight. These are provided below:

  **Table 3. Correction Factors Used to Estimate Flight Distances**

| Flight Distance | Correction to Flight Distance |
|---|---|
| Less than 50 km | + 50 km |
| Between 550 km and 5500 km | + 100 km |
| Above 5500 km | + 125 km |

- The GHG emission resulting from a trip by airplane is a function of both distance travelled and the GHG emission intensity of the specific trip. The GHG emission

[2] http://maps.google.com/

intensity of air travel is a function of a number of independent and interdependent factors which in some cases are known and in some cases must be assumed, including:

1. Trip length:
   The length of a flight dictates the type and size of the aircraft used and the total amount of fuel used in the flight. In particular, since more fuel is required to lift an airplane to 3,000 feet (termed the landing and take-off cycle, or LTO) than is required during the 'cruise' phase of the flight, shorter trips will be more GHG emission intensive when measured on a flight or a passenger kilometre traveled (PKT) basis. This assumes that an aircraft flies directly between these two airports. A 10% correction factor is applied to account for things like circling, adjustments of flight routes, headwinds, etc.

2. Aircraft type and size:
   It is also important to note that there are large variations in the fuel burn rates (FBRs) and the subsequent GHG emission intensities within the different categories of aircraft. For example, for flights above 1,600 km, the aircraft used might be a Boeing 767 300 series, an Airbus 343, or a Boeing 767 299 series, all of which have different seat configurations and technical efficiencies. In order to provide a suitable metric, a representative sample of aircraft within each distance range has been taken in order to generate an average FBR and GHG emissions intensities based on a series of distance categories.

3. Airplane engine type:
   While jet engines are still dominant for most continental and intercontinental flights, turbo prop engines are now used by some airlines. Industry literature suggests that for similar size airplane, turbo prop engines can be between 30% and 40% more efficient than aircraft powered by jet engines. This type of airplane is an option available for user selection.

4. Airplane age:
   Due to technological improvements, change in materials, improvements in aerodynamics, amongst other factors, and a drive to become more cost efficient and competitive, there are continuous improvements in the efficiency of newer airplanes. The effects of aircraft age on GHG emissions are reflected by the FCR used in estimating these. This is not a required user input.

5. Proportion of passengers to freight
   The proportion of passengers to freight on any given flight will influence the emission intensity of passenger travel. If passengers are carried on a flight, then all the emissions generated by the movement of the aircraft is distributed to the passengers. However, in the freight is also moved, in order to be accurate, the emissions associated with the freight must be allocated proportionally based on the weight of this freight. In Canada as is the case in other countries, it is generally the wide bodied aircraft that carry the most freight as a proportion of total weight of the passenger/freight load. The allocation of emissions to passengers and freight is made

according to statistics available from ICAO where it is assumed that wide bodied aircraft (used for long haul) may have freight contributing to upwards of 20% of their total load, and narrow bodied aircraft having freight contribute less than 5% to total load. This is not a required user input.

6. Class of seat:
   Each class of seat on an aircraft is responsible for a certain amount of the total GHG emission based on the "foot print" of that seat – i.e., how much space is taken up. Since seats in first/executive/business class can require up to twice the space of those in economy class, these seats account for more GHG emissions on a per passenger basis. Users can select the seating option in the calculator.

7. Airplane occupancy:
   The occupancy of a flight has an inverse relationship with the emission intensity of air travel since the more seats that are occupied on an airplane, the lower the average GHG emissions intensity of that flight per passenger. The same holds true in terms of fuel consumption, and is why airline companies continuously try to increase occupancy rates by strategic flight scheduling, etc. Aircraft occupancies have been steadily rising in Canada over the last number of years, and recent estimates are that occupancies are over 80% on most domestic flights. To be conservative, a value of 75% for all flights is used in this calculator. This is not a required user input.

- The parameters that characterize these different categories, and in turn, influence the emission intensity of each are summarized in table 3.

**Table 3. Aspects of Air Travel Affective Fuel Burn Rate**

| **Flight distance (km)** | **Example of aircraft type** | **FBR (kg/km)[a]** | **Number of seats[b]** | | **Footprint of seat (pitch * height) (inches²)[b]** | |
|---|---|---|---|---|---|---|
| | | | *Economy* | *Executive* | *Economy* | *Executive* |
| > 1,600 | Boeing 767 300 series | 5.26 | 173 | 30 | 605 | 1 230 |
| <1,600 and >500 | Airbus 320 | 3.36 | 120 | 20 | 544 | 777 |
| <1,600 and >500 | Boeing 737 300 series (only economy class) | 3.01 | 137 | | 544 | |
| <1,600 and >500 | Regional jet | 1.67 | 50-70 | | 544 | |
| <1,600 and >500 | Regional turbo prop[c] | 1.02 | 50-70 | | 544 | |
| <=500 | Dash 8 | 0.49 | 37 | | 544 | |

*Table notes:*

*a) Fuel burn rates are for the cruise cycle from the EMEP/CORINAIR Emission Inventory Guidebook (EIG)*

*b) The number and size of seats on each type of aircraft is taken from www.seatguru.com.*

*c) For regional turbo prop aircraft, industry data indicated that these aircraft are 30%-40% more fuel efficient than comparable regional jets (http://www.q400.com/q400/en/turbo.jsp).*

## Personal Passenger Vehicle

- To generate estimates of PKT for personal passenger vehicle, actual km travelled as per a mapping application that traces the road network from point of departure to point of destination, selecting the shortest distance along the road network.

- The estimation of the GHG emission for a passenger vehicle is more complex than other modes due to the wide-range of cars and trucks available and the variations in GHG emission intensities across vehicle type. Table 1 in Appendix A provides a list of typical vehicle fuel efficiencies and GHG emission intensities. To more precisely estimate the GHG emission for personal passenger vehicles, the Natural Resources Canada Vehicle Fuel Efficiency Guide 2009 may be used to identify the specific vehicle fuel consumption rating (in L/100 km) which can then be multiplied by a GHG emission factor of 2.4 kg/L for gasoline and 2.7 kg/L for diesel.

## Bus

- To generate estimates of PKT for rail, a mapping application that traces the road network from point of departure to point of destination, selecting the shortest distance along the road network.

- For passenger bus transportation, the GHG emission factor is generated from data available from the transportation tables contained in the Comprehensive Energy Use Database provided by the Office of Energy Efficiency. Specifically, the OEE provide estimates of GHG emissions and passenger kilometre traveled by intercity-bus in Canada. Analysis of this data suggests an emission intensity of 71.37 grams (0.07137 kg) of $CO_2$e per passenger kilometre traveled on intercity-bus.

## Train

- To generate estimates of PKT for rail, a mapping application using the great circle distance function calculating the distance between the origin and destination points (this is the most direct route after accounting for the curvature of the earth) is used. This is based on the assumption that rail transportation infrastructure follows closely the most direct route between major centres.

- For passenger train transportation, the GHG emission factor is generated from data available from Transport Canada’s T-Facts website.3 For passenger rail transportation, this provides data on total passenger PKT, as well as the fuel consumption associated with this activity. This allowed the calculation of GHG emissions, resulting in a GHG emissions intensity of 190.2 grams (0.1902 kg) of $CO_2$e per PKT.

[3] http://www.tc.gc.ca/pol/en/T-Facts3/Statmenu_e.asp?type=pu&file=rail&Lang=