Community Energy and Emissions Inventory: On-Road Vehicle Emissions Inventory Methodology

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Introduction

On-road transportation emissions averaged 23% of total greenhouse gas (GHG) emissions in British Columbia from 2007-2021. The Province has set a sectoral target to reduce transportation emissions 27-32% below 2007 levels by 2030. Local governments can influence on-road transportation emissions and have committed to reporting community-wide emissions as part of the Climate Action Charter. Multiple Union of B.C. Municipalities resolutions have called for timely, community-level, transportation emissions data.

The Climate Action Secretariat (CAS) engaged Licker Geospatial Consulting Ltd. (LGeo) to develop a reliable, annual, community-level on-road transportation emissions inventory alongside a reproducible methodology for annual updates. The purpose of this document is to provide a summary of the methodology as well as a discussion of its strengths and weaknesses. The intention of the report is to be transparent and concise so that it is understandable to the general public.

In addition to informing community-level climate policy, this dataset (herein referred to as the CEEI On-Road Transportation Dataset or 'the dataset') can be used to develop supporting indicators for transportation policy at the provincial and community level. The dataset includes data on vehicle populations by fuel-type and category. It also provides estimates of liter equivalents of fuel used and vehicle kilometers travelled.

Acronyms

CAS	Climate Action Secretariat
CEEI	Community Energy and Emissions Inventory
CH	Conventional Hybrid
GHG	Greenhouse Gas
HDT	Heavy Duty Truck
ICBC	Insurance Corporation of British Columbia
IPCC	Intergovernmental Panel on Climate Change
LDT	Light Duty Truck
LGeo	Licker Geospatial Consulting
MDT	Medium Duty Truck
MECCS	Ministry of Environment and Climate Change Strategy
NIR	National Inventory Report
NRCan	Natural Resources Canada
PYE	Policy Years Earned
SUV	Sport Utility Vehicle
ktCO2e	Kilotonnes Carbon Dioxide Equivalent
VKT	Vehicle Kilometers Travelled
VIN	Vehicle Identification Number
ZEV - BEV	Zero Emissions Vehicle - Battery Electric Vehicle
ZEV - Other	Zero Emissions Vehicle - Other (typically hydrogen)
ZEV - PHEV	Zero Emissions Vehicle - Plug-in Hybrid Electric Vehicle

Methodology

Modelling Assumptions

Key assumptions in the emissions modeling methodology are enumerated below:

- It is assumed that the input data that are used for emissions calculation are representative of their target populations;
- Vehicle emissions are attributed to the postal code of the insurance record. This is especially relevant for buses because the lower mainland buses are all registered in New Westminster. It also means that vehicles registered outside the Province are not included in the created CEEI On-Road Transportation Dataset;
- It is assumed that the insurance policy years earned are a representation of the amount of time that a vehicle is driven in a year;
- Vehicle categorization primarily relies on VIN decoding, but in certain cases where VINs could not be decoded the ICBC body style was used exclusively. In these cases, the categorization is somewhat arbitrary because it depends on the vehicle body style that is selected by the ICBC staff;
- The process to fill in missing years interpolates trends in the existing data. Vehicle population data is most accurate for the years 2007, 2012, and 2019 onward.
- Vehicle kilometres travelled (VKT) estimates were calculated for each vehicle category, community, and year using a combination of data sources, including bottom-up sources that are attributed to individual vehicles (AirCare records) and top-down sources that estimate total VKT for given years and communities (TripDiary Surveys and NRCan records). The VKT numbers have the highest uncertainty of all data inputs.
- A post-facto adjustment is made to the calculated litres consumed so that the top-line values match the National Inventory Report (NIR) for each year, fuel type and vehicle category.

Emissions Calculation

The methodology for modeling emissions from on-road vehicles in BC is similar to the methods developed in the 2021 Canadian *National Inventory Repor*t (NIR). The NIR describes and applies a method for developing GHG inventories using the sectoral approach from the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006).

This approach multiplies fuel consumed with country-specific emissions factors to determine GHG emissions. The fuel consumed by each vehicle depends on the vehicle kilometers travelled (VKT) alongside the engine economy. Emissions from each vehicle are described by the following equations:

Per vehicle GHG Emissions (ktCO2e) = Economy (L/100km) * Emissions Factor (ktCO2e/L) * VKT (km) (1)

Total GHG Emissions (ktCO2e) = sum of Per vehicle GHG Emissions (ktCO2e) (2)

To perform the above calculations the vehicles are grouped by fuel type, vehicle category, community, and year. The engine economies of the vehicles depend on their age, so model years are also taken into account in this step. The GHG emissions per vehicle type are then calculated for each grouping. The GHG emissions for each group are multiplied by the total population of vehicles within the group.

The GHG emissions are based on the relevant attributes on each vehicle and they are assigned to the following categories:

OtherVans Motorhome LDT MDT Passenger PublicTransitBus

Minivan Motorcycle HDT Bus SportsCar Taxi/Limo SUV

and fuel types:

Gasoline Diesel ZEV - BEV CH ZEV - PHEV NaturalGas Other ZEV - OTHER

The categories and fuel types are assigned according to the VIN attributes. For category this is done based on the body class/style according to predefined rules that are defined in an excel spreadsheet that is provided as an input. For fuel type, this is assigned based on primary and secondary fuel types, alongside the vehicle electrification level.

Data Output Units

The reported units in the data output are as follows:

- Total Emissions (ktCO2e)
- Litres Equivalent (Litres)
- Total VKT (km)
- Total PYE (years)

Model Inputs

Each of the key inputs described in the sections below are required to run emissions calculations. For the current release, LGeo has prepared these inputs for each year from 2007-2021. A brief overview of the inputs is provided here.

EMISSIONS FACTORS

For vehicles, the emissions factors measure the amount of Carbon Dioxide equivalents (CO2e) per liter of fuel. The emissions factors vary between different fuel types but also between vehicle categories. BC-specific emissions factors for on-road vehicles have already been developed and reported by the Ministry of Environment and Climate Change Strategy (MECCS) in: *2020 B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions* by the Ministry of Environment & Climate Change Strategy (MECCS). British Columbia's Renewable and Low Carbon Fuel Requirements Regulation[1] is also incorporated into the inventory.

ENGINE ECONOMIES

Vehicle engine economies indicate how much fuel the vehicle will consume per 100km driven. They differ between vehicle types and fuel types, and newer vehicles tend to be more economical. For this project, engine economies were largely derived from NRCan and B.C. transit data.

The economy of a vehicle engine can vary widely depending on whether it is being driven in the city or on a highway. To account for this, a combined engine economy for the majority of vehicle types were calculated using the following formula:

$$\text{Fuel Economy} = \text{City Economy} * \text{City Proportion} + \text{Hwy Economy} * \text{Hwy Proportion} \quad (3)$$

where the city and highway proportions represent the amount of each type of road in the province (75% and 25%, respectively). It was assumed that buses only drive in the city and that heavy duty trucks and motorhomes only drive on the highway.

[1] Part 2 of this Act requires that fuel supplies include renewable content into diesel and gasoline fuels, starting with 3% and 5% renewable content respectively, and increasing thereafter.

VEHICLE KILOMETERS TRAVELLED (VKT)

The vehicle kilometers travelled represent the expected average distance travelled by the vehicles within each community, by vehicle category. The expected VKT will also change between different years as driving behaviors shift.

Of all the model inputs VKT has the highest uncertainty, since there is no systematic data collection for driving behaviors in BC. In lieu of better information, LGeo estimated VKT using a combination of data sources including: bottom-up, or disaggregated, sources that are already attributed to individual vehicles (AirCare records); and top-down sources that estimate the sum total VKT for given years and communities (TripDiary Surveys). Using these two sources, VKT estimates were derived for each vehicle category, community and year.

VEHICLE POPULATIONS

ICBC vehicle insurance records were the data used to calculate the amount of on-road vehicles throughout the Province. Insurance information (such as Postal Code and policy years earned (PYEs), the vehicle identification number (VIN) and attributes such as ICBC-determined make and model are all included.

The ICBC data is very large and involves complex processing such as VIN decoding (a process by which the VIN is decoded to determine vehicle-specific attributes such as the weight, body class and electrification level) and vehicle categorization.

The ICBC insurance records are the best available source for vehicle population data. However, data exploration performed by the LGeo team and CAS identified some deficiencies in the data. In particular:

1. There was no usable data for any years prior to 2007, or from 2008-2011, but the years 1990 onward are required for this inventory. To address this issue vehicle population backcasting was performed, as described in the section below.
2. The amount of data 2013-2018 are systematically lower than for the years 2007, 2012, and 2019-2020; the former only includes vehicles that were insured in the last quarter of the year so a substantial number of records are missing. A multiplier is applied to the policy years earned in the years with missing data.

Estimating Missing Years

This release includes data from 2007-2021. Data is missing for the years 2008-2011. To complete the CEEI On-Road Transportation Dataset, missing years must therefore be estimated. For this work, the methodology involves interpolating PYE values for the missing years based on those that are available. Since the years 2008-2011 have available data on either end (2007 and 2012 onward) PYE informed, linear trends can be built between the years to fill in the missing values.

Calibrating to the NIR

The CEEI On-Road Transportation Dataset is coherent with the levels and trends of the on-road transportation line-item in the National Inventory Report (NIR). This is due to an ex-post correction of VKTs, LEs, and GHG emissions to match the NIR. This correction is similar to a correction used by ECCC in the preparation of the bottom-up inventory that is used for the NIR. After computing variables using our bottom-up methodology we:

1. Back-calculated liters consumed from emissions in the NIR data, for each vehicle category in the NIR;
2. Calculated the calibration ratio between our modelled liters consumed and NIR's back-calculated liters consumed for each vehicle category and year;
3. Used this calibration ratio to adjust VKTs and, accordingly, liter equivalents.
4. Re-calculated emissions using the emissions factors and the liter equivalents.

The result is a dataset that has trends and emissions levels that are consistent with Provincial Inventory and the NIR.

Discussion

The methodology and data output associated with this report represent a user-friendly version of the most comprehensive community-level on-road vehicle emissions inventory built to date. The application of ICBC vehicle insurance records results in an inventory that is truly bottom-up, that is, calculated on a vehicle-by-vehicle basis instead of in the aggregate. As such, the provided inventory is truly policy responsive.

Uncertainty Analysis

In developing the methodology and the inputs used to create the CEEI On-Road Transportation Dataset, LGeo undertook an extensive and comprehensive review of available data. The result is the most accurate community-level on-road emissions model currently available in B.C., but it must be noted that the data inputs are of variable quality: for this project uncertainty resulting from the input data is **much** more significant than methodological[2] uncertainty. Future iterations of this data product will incorporate improved data on VKTs and vehicle populations from ICBC. Specific considerations for each input are discussed below.

Input	Certainty	Notes
Emissions Factors	Medium - High	Emissions factors are predefined by the Province of B.C. and will hold the same degree of uncertainty. Of all the factors, the B.C. Hydro electricity factor has the highest degree of uncertainty.
Engine Economies	Medium	The engine economies are mostly based on aggregated NRCan values. Further, the methodology does not account for the load carried by the vehicle, idle time, topology, etc.
Vehicle Kilometers Traveled	Low	Of all the inputs VKT had, by far, the lowest degree of certainty. Across all vehicle types there was no reliable source of VKT data so the project team was required to make projections based on disparate, incomplete, or aggregate data sources that are unlikely to capture true driving behavior. Further, any external behavioural factors (such as introduction of more transit or bike lanes) cannot be captured. Particularities of the VKT assumptions for each vehicle type are in Appendix A.
Vehicle Populations		
• 2007, 2012, 2019 on	High	ICBC provided complete data for these years so there is a high degree of certainty.
• 2013-2018	Medium +	ICBC provided partial data for these years. There is a degree of certainty but a multiplicative factor had to be applied to account for missing data. This factor may be too simple to capture annual trends,

[2] Most of the methodological uncertainty for this project revolves around the computational limitations of excel. In particular, the granularity of the input data had to be reduced so that there wasn't too much memory consumed. For example - an average engine economy is used for each vehicle type and age, when in reality the economies may vary across make-model.

		such as different vehicle types that are more likely to be insured in the summer.
• 2008-2011	Medium -	ICBC did not provide any usable data for these years. In lieu of better information, PYE estimates were made by building trends off of the available years. As discussed above, the scale of the other years depends on a multiplicative constant assigned by the user, so the estimates for 2008-2011 will also depend on this constant.

Appendix A

Particularities of the VKT assumptions for each vehicle type are discussed below:

- Passenger: The closest data to a source of truth that is available is Trip Diaries and AirCare. Trip Diaries studies are limited to few communities, small sample sizes, few years, and possible human error. Still, the trends in the deliverable depend exclusively on the trends found in the Trip Diaries. We have no information on driving patterns in communities north of Kamloops or IRIs. The AirCare data was only for 2007-2014(Q1), and actually represents driving patterns of a small subset of old vehicles in Metro Vancouver. VKT for newer vehicles was estimated with regression, and we assigned the discovered VKT to different archetypes even though they primarily drive in Metro Vancouver.
- Taxis/Limos: There is no known data on the driving patterns of taxis or limos, so the project team performed a general calculation based on assumed driving time and speed (see Section 8). Data collection efforts would need to be undertaken to test the reliability of these assumptions.
- Public Transit Buses: The only data made available was VKT for 2019. This was applied across all years, so changes in VKT across time could not be captured.
- MDTS, HDTS: There is no known information for VKT on these vehicles. To handle this, the project team took the mean KT per vehicle based on a provincial aggregate from NRCan. This will not represent differences between communities, vehicle types within the category (many types were put into MDT), etc.