Clean Air Benefits from Electric Vehicles

Potential impacts of additional electric vehicles in City of Campbell River, the Peace River Region and City of Richmond

Prepared for

Clean Air Research BC

Prepared by

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Executive summary

The overall goal of this project is to conduct research on air quality benefits of electric vehicles as a means to help manage air quality in B.C. communities. This research has the objective to:

Estimate air quality impacts for three B.C. communities from adoption of electric vehicles

The air quality impacts estimated are community-wide annual emissions of

- Greenhouse gases – carbon dioxide, methane, nitrous oxide
- Local air pollutants – carbon monoxide, nitrogen oxides, volatile organic compounds, sulphur oxides and particulate matter

Personal vehicles running on gasoline or diesel emit pollutants with significant health impacts, and also make large contributions to greenhouse gas emissions. Electric vehicles in British Columbia provide significant reductions in greenhouse gas emissions and local air pollutants, due to the province's clean electricity.

This research comprises three communities: Campbell River, Richmond, and the Peace River Regional District. Two scenarios were developed for each community: a reference case, with minimal EV uptake in the community, and an EV scenario. The EV scenario assumed that 1.4% and 24% of passenger vehicle stock in 2020 and 2035 respectively would be EVs, based on the assumptions from BC Hydro's 2012 Draft Integrated Resource Plan.

Key results

Electric vehicles will lead to reductions in GHG and air pollutant emissions in the communities evaluated. Overall reductions of about 1% in both greenhouse gas emissions and air pollutants from passenger vehicles and light truck could be expected by 2020, based on sales of new EVs growing to 10% of all sales by 2020.

Much higher reductions, up to 25%, could occur by 2035, assuming sales of EVs continue to grow significantly.

Reductions are relative to reference case pollution levels for passenger cars and light trucks in that year.

The combination of increased fuel efficiency due to Canadian regulations for passenger vehicles plus more electric vehicles will allow communities in British Columbia to significantly reduce greenhouse gas emissions relative to 2007 levels.

Key assumptions and caveats

The modeling in this analysis is based on simplifying assumptions. The following assumptions would benefit from additional research if resources are available.

In the reference case, the estimated uptake of electric vehicles in British Columbia due to the federal GHG regulations for light duty vehicles is not specified but assumed to be low. Further research on the likely sales impact in Canada and by province will be useful to provide a full picture of electric vehicle uptake.

It is assumed that emissions per kilometre of local air pollutants (CO, NOx, SO2, VOC, and PM) do not change over time in the reference case. This assumption, based on output from the GHGenius model, could be tested more thoroughly.

The EV case assumes that by 2035 almost half of new car buyers will be buying electric vehicles: 45% of passenger cars and light trucks will be electric. The performance of future EVs will need to continuously improve in order to meet this fraction of new vehicle sales.

The assumption that the electric vehicles in the EV scenario will be either battery electric or plug in hybrid electric vehicles running primarily on electricity leads to higher emissions savings than if it is assumed a high uptake of plug in hybrid electric running significantly on gasoline. Again the performance of electric vehicles will need to improve and / or be supplemented by government policies to encourage this pattern.

This analysis assumes that travel behaviour in the future will be similar to current behaviour. In particular the estimates are based on similar number of vehicles per population and kilometres traveled per vehicle.

Life cycle emissions

To check the overall impact of EVs, Pembina also considered life cycle emissions, covering upstream fuel production and distribution as well as vehicle material and assembly. This analysis, based on results of the GHGenius model, demonstrated the overall emissions are lower for EVs than for gasoline vehicles: GHGs are reduced by approximately 82% over the lifetime of an EV, compared to a gasoline vehicle. Local air pollutants were reduced by 36% for PM, 45% for SOx, 96% for VOCs, 81% for NOx and 99% for CO.

Next steps for municipalities

Reaching the environmental benefits identified in this report will require additional actions to support electric vehicles. Auto manufacturers and battery developers are striving to produce EVs with lower capital costs and a wider range of performance features. The public sector can also support EVs through policies and incentives. Actions by local governments to support electric vehicles include providing information and demonstrations, reducing barriers where possible and using signs and websites to help residents and visitors locate charging stations for EVs. Working with car-share organizations to support EVs and reducing development cost charges for new developments with EV charging stations are also strong actions that should be considered. Municipalities that are promoting their own "green" actions should ensure that actions supporting EVs are included.

EVs are only part of the solution. Most communities will need to also consider other initiatives in order to meet their climate and clean air objectives. Municipalities in B.C. are encouraged to explore opportunities to strive for the cleanest transportation for their communities such as reducing the need for long-distance travel by personal vehicles, encouraging walking and cycling, and when necessary, using the least polluting vehicles.

1. Introduction

1.1 Project context and rationale

Local governments are looking for options to improve air quality in their communities and to contribute to mitigation of global climate change. Increased use of electric vehicles is one of many potential solutions for local governments. The research in this proposal will help local governments understand the extent to which electric vehicles can contribute to improved air quality in their communities

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1.2 Air emissions from passenger cars and light trucks

Burning fossil fuels in the engines of passenger cars and light trucks causes air pollution that both contributes to global climate change and reduces local air quality. Climate change and air quality are two different phenomena. Global climate change is caused by the overabundance of greenhouse gas (GHG) emissions in the atmosphere. Emissions from vehicles in B.C. communities can contribute to changes in regional temperatures, precipitation patterns and storm frequency throughout the world. Local air quality generally refers to level of pollutants in air that we breathe, the lowest part of the atmosphere. Air quality is reduced by excess concentration of specific pollutants. The sections below describe the environmental and human health impacts of climate change and reduced air quality in the context of B.C. communities.

1.2.1 Greenhouse gas emissions

Local governments in British Columbia have been required to undertake actions to reduce their community GHG emissions since 2010, with many communities starting many years prior to that. Amendments to the *Local Government Act* contained in Bill 27, 2008, the *Local Government (Green Communities) Statutes Amendment Act*, were designed to enable local governments to take action to reduce community-wide greenhouse gas emissions, and transition to compact, complete and more energy-efficient communities.

The amendment meant that local governments needed to develop and include GHG reduction targets in official community plans by May 31, 2010. In addition, local governments must also include policies and actions that support the GHG reduction targets.[1]

Approximately 14% of the province's GHG emissions are from passenger vehicles and light trucks. This fraction is higher in the communities considered for this report, however, as seen in Figure 1 below. Note that in the Peace River region, passenger vehicles and light trucks account for a smaller fraction of GHG emissions than in Campbell River or Richmond. This is due to a large number of commercial vehicles and tractor trailer trucks in the Peace River region.

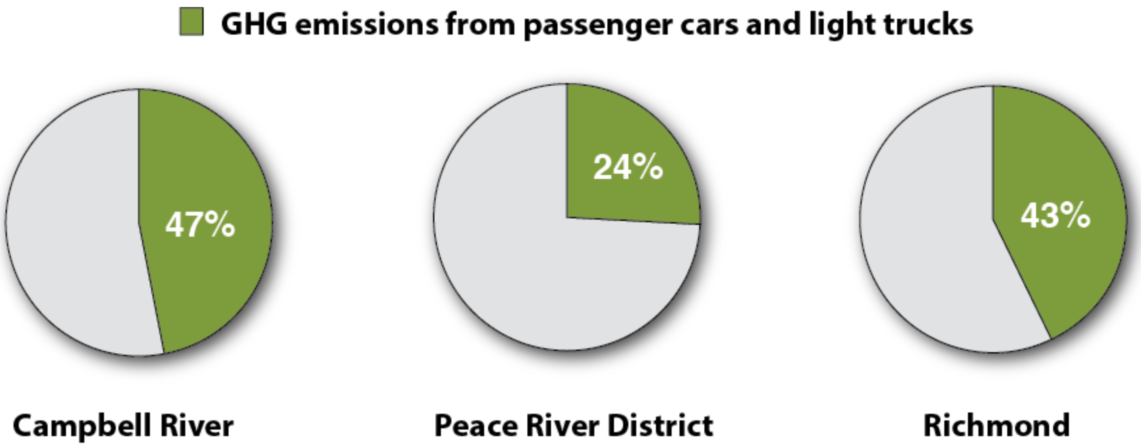

Figure 1. Fraction of GHG emissions from passenger cars and light trucks

Source: B.C. Ministry of Environment[2]

The British Columbia Ministry of Environment's research states:

"The best available science suggests that the impacts for B.C. in the 21st century will include:

- *A 2-5°C increase in average annual temperature;*
- *Increased river flood risks in the spring and coastal flooding associated with storm surges;*
- *Glacial retreat in the south; reduced winter snow pack and earlier snowmelt; contributing to reduced summer water supply; and*
- *Increased stress on species at risk; shifts in the geographical range of vegetation, including economically important forest species;*
- *Increased river temperatures and stress on salmon; and*
- *Reduced summer soil moisture and increase in forest fire risk."* [3]

[1] B.C. Ministry of Community, Sport and Cultural Development, "Greenhouse Gas (GHG) Emission Reduction Targets, Policies and Actions." http://www.cscd.gov.bc.ca/lgd/greencommunities/targets.htm

[2] B.C. Ministry of Environment, *Community Energy and Emissions Inventory*, 2007. http://www.env.gov.bc.ca/cas/mitigation/ceei/archive_2007/RegionalDistricts/master_index.htm

[3] B.C. Ministry of Environment, "Climate Change: Provincial Impacts," http://www.env.gov.bc.ca/cas/impacts/bc.html

1.2.2 Local air pollutants from personal vehicles

In addition to greenhouse gas emissions, personal vehicles running on gasoline or diesel emit pollutants with significant health impacts. Burning fossil fuels in motors leads to emissions of carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOC, which contribute to formation of ozone), and sulphur oxides (SO_x). The effects of these emissions on human and environmental health are summarized in Table 1.

Table 1. Health impacts of local air pollutants from personal vehicles (gasoline or diesel)

Pollutant	Description	Human Health Effects	Environmental effects
Carbon monoxide (CO)	Colourless, odourless gas emitted from combustion processes.	Exposure to CO can reduce the oxygen-carrying capacity of the blood. This can particularly affect people with heart disease and compromised abilities to respond to the increased oxygen demands of exercise or exertion.	CO contributes to the formation of smog, ground-level ozone (see VOCs below)
Nitrogen oxides (NO_x)	Group of highly reactive gases that include nitric oxide (NO) and nitrogen dioxide (NO_2); NO_2 is odorous, brown and highly corrosive	Aggravation of respiratory disease and increased susceptibility to respiratory infections; contributes to ozone and PM formation (see impacts below)	Contributes to acidification and nutrient enrichment of soil and surface water; contributes to ozone and PM formation (see impacts below)
Volatile organic compounds (VOC)	VOCs combine with NO_x to form ozone.	Breathing ozone can trigger chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma as well as reducing lung function. Repeated exposure may permanently scar lung tissue.	Ground level ozone can have harmful effects on sensitive vegetation and ecosystems, including loss of species diversity and changes to habitat quality and water and nutrient cycles.
Sulphur oxides (SO_x)	Colorless gases formed by burning sulfur. Sulfur dioxide (SO_2) is the criteria pollutant that is the indicator of SO_x concentrations in the ambient air.	SO_2 causes aggravation of asthma and increased respiratory symptoms; contributes to PM formation (see impacts below).	SO_2 contributes to acidification of soil and surface water and mercury methylation in wetland areas; contributes to PM formation (see impacts below).
Particulate matter (PM)	Microscopic solid and liquid particles that are suspended in the atmosphere.	Aggravation of respiratory and cardiovascular disease, reduced lung function, increased respiratory symptoms	Impairment of visibility, effects on climate, and damage and/or discolouration of structures

		and premature death.	and property.

Source: B.C. Lung Association[4]

Personal vehicles are only one source for the air pollutants; other sources include combustion of fossils fuels for heat and industrial services, forest fires and dust (especially for particulate matter). Table 2 shows the percentage of local air pollutants caused by light duty vehicles for the whole province. The percentage in individual communities will vary significantly based on industries in each location. Table 2 includes both the contribution of light duty vehicles from operations (driving) and the contribution when pollution levels due to driving are combined with pollution levels from all aspects of transportation and the petroleum industry in British Columbia. Driving of light duty vehicles has significant contributions to CO, NOx and VOC pollution but low contributions to SOx and TPM pollution levels (unless the dust from road vehicles is included in the latter).

Table 2. Contribution of light duty vehicles to local air pollution in British Columbia

Pollutant	Pollution share due to light duty vehicles operation	Pollution share due to all transportation operations and B.C.'s petroleum industry
Carbon monoxide (CO)	35%	71%
Nitrogen oxides (NOx)	9%	86%
Volatile organic compounds (VOC)	14%	46%
Sulphur oxides (SOx)	0.2%	72%
Total particulate matter (TPM)	0.02%*	1%

*. The vast majority (83%) of TPM emissions are due to dust from paved and unpaved roads

1.3 What are EVs?

Electric vehicles include a range of vehicle types that use electricity for part or all of their fuel supply. They range from the hybrid cars that have been mass marketed for several years, to fully electric vehicles that have no tailpipe and "fill-up" only by plugging in (Figure 3). The range of EVs provides a transition from a diesel or gasoline-fuelled internal combustion engine vehicle, and provides corresponding reductions in greenhouse gas emissions. Different EVs will suit the needs of different owners.[5]

[4] Table based on information in BC Lung Association, *2012 State of the Air Report,* http://www.bc.lung.ca/airquality/documents/StateOfTheAir2012-Web.pdf which references U.S. Environmental Protection Agency, *National Air Quality Status and Trends Through 2007*, report EPA-454/R-08-006 (2008).

[5] Transport Canada, "Electric Vehicle Primer," 2010. http://www.tc.gc.ca/eng/programs/environment-etv-evprimer-eng-1994.htm

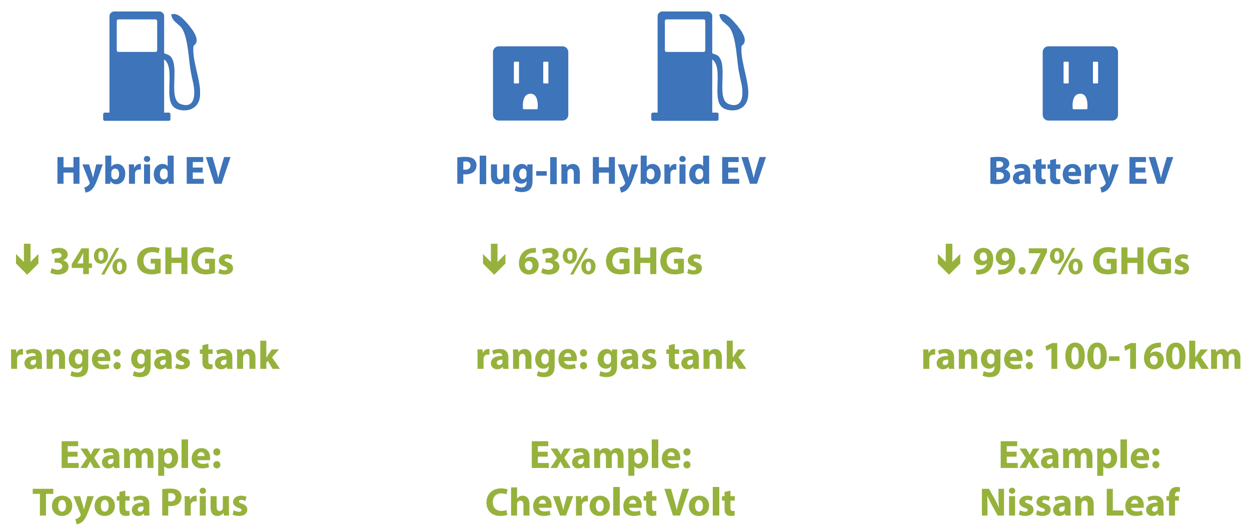

Figure 2. Electric vehicles include a range of choices, from hybrids to fully battery electric vehicles

1.3.1 Hybrids

Hybrids are closest to a conventional vehicle. They have a gasoline engine, as well as a small electric motor and a battery. They fuel up at a gas pump, and re-charge the battery using regenerative braking and the gasoline engine. Use of the electric motor reduces gasoline use, improving the hybrid's fuel economy over a conventional internal combustion engine vehicle. They emit about one-third fewer GHGs than a conventional vehicle,[6] and their range is the same as or better than an equivalent conventional vehicle.

1.3.2 Plug-in hybrids

Plug-in hybrid electric vehicles, or PHEVs, are now coming to mass market. They have a gasoline engine and an electric motor and battery. They fill up the gas tank at a gas pump, and plug in to charge the battery. They drive using the electric motor until the battery is depleted (currently up to 80 kilometres), after which the gas engine kicks in. This means that they can combine the fuel savings of a plug-in electric vehicle with the range of a conventional internal combustion engine vehicle. Examples of PHEVs are the Toyota plug-in Prius and the Chevrolet Volt. PHEVs work well when a car owner wants an electric vehicle for local/city driving, but also occasionally needs to travel long distances.

1.3.3 Battery electric vehicles

Battery electric vehicles, or BEVs, are fully electric vehicles that do not have an internal combustion engine. They are fuelled by plug-in only, and have no tailpipe and hence no tailpipe emissions. Their range is currently about 100 to 160 kilometres, although the high-end sportscar,

[6] Modeled results for greenhouse gas reductions are detailed in *Electric Vehicles: Powering the Future* (Pembina Institute, 2010), 16-19. http://www.pembina.org/pub/2072

the Tesla Roadster, has a range of approximately 300 kilometres.[7] Examples of BEVs include the Nissan Leaf and the Mitsubishi i-MiEV. BEVs are ideal for car owners who will be doing their driving within the community.

The availability of electric vehicles is increasing as the major car manufacturers bring more into production. For example, in addition to the Chevy Volt plug-in hybrid already available, Ford is bringing out a Ford Focus plug-in hybrid in 2013. Toyota plans to have over 21 hybrids available by 2015.[8] Nissan has the fully electric Leaf available now, and Mitsubishi has the i-Miev. Hybrid SUVs and trucks are also in the market, with more on the way.

Lastly, fully electric vehicles also include mobility scooters, e-bikes, and golf-cart style low-speed vehicles. These electric vehicles can help meet the mobility needs of a broad range of community members, including seniors, and local governments should consider increased use of such vehicles in planning and environmental considerations.

[7] BEV range depends on a number of factors, including driving conditions. For the Tesla, see http://www.teslamotors.com/blog/model-s-efficiency-and-range.

[8] Communication from the Toyota dealership in Campbell River, October 2012; see also Chester Dawson, "Toyota Details Broader Hybrid Lineup," *The Wall Street Journal*, September 24, 2012. http://online.wsj.com/article/SB10000872396390444358804578015543548693774.html

2. Research approach

2.1 Choice of communities

This report includes results from modelling the impacts in two municipalities (Campbell River and Richmond) and one regional district (Peace River). These communities have shown support for electric vehicles through engaging in planning processes for EV charging stations. Campbell River has run its own planning process, while staff at Dawson Creek and Fort St. John developed an EV charging station planning workshop that covered the Peace River Region. Richmond is supporting a regional process through Metro Vancouver.

The three communities provide a mix of urban and rural locations, with temperate and northern climates.

2.2 Stock turnover model

Pembina's stock turnover model is designed to estimate the change over time of emissions from a "stock" of vehicles based on changes to efficiency or emission rates of new vehicles. In other words, you may know that the average new vehicle today is 3% more efficient than last year's model, but need to know the change in emissions for the entire community that includes both new cars from this year and many cars from previous years. The stock turnover model uses projected fuel efficiency of new vehicles as input, and calculates the resulting changes in stock fuel efficiency as older vehicles retire and new vehicles are purchased.

The input to the stock turnover model are the fuel efficiency and the emissions rates (grams of pollutant per kilometre) of new vehicles, the growth rate of new vehicles and age of vehicles (for retirement calculations). The model uses one average rate for all cars purchased in the same year and one for light trucks (for each year). Disaggregation to different types of vehicles is possible with the model structure, but was not done for this report. The data on vehicle purchases in past years and projections for fuel efficiency for future years was not readily available for different types of cars and trucks.

2.2.1 Fuel efficiency rates for model

The input assumptions for fuel efficiency of gasoline and diesel vehicles in the model reflect recent regulations by governments in Canada and the United States. In 2010, the Canadian federal government implemented the *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations*, which set maximum GHG standards for new passenger cars and trucks for the model years 2011 to 2016.[9] The *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations* are aligned with the U.S. regulations for passenger vehicles in that time period. In November 2012, the Canadian government announced proposed regulations that

[9] Government of Canada, *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations*, SOR/2010-201. http://www.gazette.gc.ca/rp-pr/p2/2010/2010-10-13/html/sor-dors201-eng.html

extend GHG regulations for passenger vehicles for the model years 2017 to 2025. The media backgrounder states

> *For model years 2017 to 2025, cars will be required to achieve, on average, 5% annual reductions in GHG emissions. As light trucks are typically used by farmers and construction workers, it is equally important that these vehicles can perform the work they are required to do. To that end, the proposed regulations provide short-term relief in the form of less-aggressive annual reductions. Consequently, light trucks will be required to achieve, on average, 3.5% annual GHG emission reductions from model year 2017 to 2021 and 5% reductions from 2022 to 2025. This will give time for companies to find technological solutions that lead to reduced emissions without affecting the utility of their trucks.*[10]

Table 3 presents the assumed fuel efficiency of new passenger cars and light trucks based on the final and proposed regulations described above.

Table 3. Assumed fuel efficiency and GHG emissions intensity of new vehicles in Canada

Model year	Fuel efficiency (litres/100km)		GHG emissions intensity (g CO_2e/km)*	
	Cars	Light Trucks	Cars	Light Trucks
2012	6.8	9.6	167	235
2013	6.7	9.4	164	230
2014	6.5	9.2	160	226
2015	6.3	8.9	155	217
2016	5.8	8.4	142	206
2017	5.5	7.7	135	188
2018	5.2	7.4	128	182
2019	5.0	7.2	122	175
2020	4.7	6.9	116	169
2021	4.5	6.7	110	163
2022	4.3	6.4	104	155
2023	4.1	6.0	99	147
2024	3.9	5.7	94	140
2025	3.7	5.4	89	133

* GHG emissions intensity is calculated from fuel efficiency.

Data sources: Lawson, Environment Canada[11]

2.2.2 Air pollutant factors from GHGenius

GHGenius is a model that estimates the greenhouse gas emissions and local air pollutants of a vehicle, including life cycle emissions — fuel production, vehicle manufacturing and vehicle

[10] Environment Canada, *Backgrounder: Regulating Greenhouse Gas Emissions from Light-Duty Vehicles (2017-2025)*, November 27, 2012. http://www.ec.gc.ca/default.asp?lang=En&n=56D4043B-1&news=1F13DA8A-EB01-4202-AA6B-9E1E49BBD11E

[11] John Lawson, *Technical Report on Analysis of Proposed Regulation of Passenger Automobile and Light Truck Greenhouse Gas Emissions,* prepared for Environment Canada (2010).
Environment Canada, *Backgrounder: Regulating Greenhouse Gas Emissions from Light-Duty Vehicles (2017-2025).*

operations. The GHGenius model is owned and managed by Natural Resources Canada.[12] GHGenius is the reporting standard used for British Columbia's *Renewable and Low Carbon Requirements Regulation.*[13]

GHGenius was used to generate input values for the Pembina stock turnover model. GHGenius provides emission factors for new vehicles in each year. This information is input to the stock turnover model, which then estimates changes to emissions from the entire stock of new and existing vehicles.

Pembina used GHGenius to estimate current and future air pollutants from vehicles\ *operations* (tailpipe emissions), which in GHGenius are derived from MOBILE6.2c.[14] Version 4.02a of the GHGenius model was used for this analysis.

GHG-Genius was run for years 2000, 2012, 2020 and 2035 with the following input selections:

- B.C. was selected as region.
- The fuel efficiency of new vehicles was revised to reflect new GHG regulations from the Canadian government (through 2016) and final regulations from the United States for 2017 to 2025. See discussion on fuel efficiency above.
- All other default values in GHGenius, 4.02a, were used.

The output from GHGenius based on above assumptions is summarized in following tables for gasoline vehicles (average across light duty cars and passenger trucks). Note that EVs have zero emissions from vehicle operations.

Table 4. Air pollution from gasoline-power vehicles

	Pollution (grams / kilometre)			
	2000	**2012**	**2020**	**2035**
CO				
Vehicle Operation	11.24	10.86	10.86	10.86
Upstream	0.07	0.04	0.03	0.02
Vehicle Material & Assembly	0.02	0.01	0.01	0.01
Total	**11.33**	**10.92**	**10.90**	**10.90**
NOx				
Vehicle Operation	0.54	0.24	0.24	0.24
Upstream	0.26	0.15	0.11	0.08
Vehicle Material & Assembly	0.08	0.04	0.03	0.02
Total	**0.88**	**0.42**	**0.37**	**0.34**
VOC-Ozone weighted				
Vehicle Operation	0.37	0.27	0.27	0.27
Upstream	0.15	0.08	0.05	0.03
Vehicle Material & Assembly	0.02	0.02	0.01	0.01
Total	**0.54**	**0.36**	**0.33**	**0.31**
SOx				

[12] GHGenius, "Model History." http://www.ghgenius.ca/about.php

[13] Government of British Columbia, *Renewable and Low Carbon Fuel Requirements Regulation,* Reg. 394/2008. http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/1231636805

[14] Don O'Connor, personal communication, August 15, 2012.

Vehicle Operation	0.046	0.009	0.006	0.003
Upstream	0.34	0.16	0.10	0.06
Vehicle Material & Assembly	0.09	0.05	0.04	0.03
Total	**0.48**	**0.22**	**0.14**	**0.09**
PM				
Vehicle Operation	0.02	0.02	0.02	0.02
Upstream	0.04	0.01	0.01	0.00
Vehicle Material & Assembly	0.05	0.03	0.02	0.01
Total	**0.11**	**0.05**	**0.04**	**0.03**

Source: Output from GHGenius model Version 4.02a based on input assumptions by Pembina.

Table 5. Air pollution from battery electric vehicles

	Pollution (grams / kilometre)			
	2000	**2012**	**2020**	**2035**
CO				
Vehicle Operation	-	-	-	-
Upstream	0.12	0.06	0.06	0.07
Vehicle Material & Assembly	0.07	0.03	0.01	0.01
Total	**0.19**	**0.08**	**0.08**	**0.08**
NOx				
Vehicle Operation	-	-	-	-
Upstream	0.13	0.04	0.03	0.03
Vehicle Material & Assembly	0.18	0.09	0.04	0.03
Total	**0.31**	**0.13**	**0.07**	**0.06**
VOC-Ozone weighted				
Vehicle Operation	-	-	-	-
Upstream	0.00	0.00	0.00	0.00
Vehicle Material & Assembly	0.02	0.02	0.01	0.01
Total	**0.03**	**0.02**	**0.01**	**0.01**
SOx				
Vehicle Operation	-	-	-	-
Upstream	0.06	0.02	0.02	0.02
Vehicle Material & Assembly	0.26	0.12	0.06	0.04
Total	**0.32**	**0.14**	**0.08**	**0.06**
PM				
Vehicle Operation	-	-	-	-
Upstream	0.02	0.01	0.01	0.01
Vehicle Material & Assembly	0.08	0.04	0.02	0.01
Total	**0.09**	**0.05**	**0.03**	**0.02**

Source: Output from GHGenius model Version 4.02a based on input assumptions by Pembina.

2.3 Scenarios

For this analysis, we ran two scenarios and compared the differences in GHG emissions and air pollutants between the two scenarios. Each scenario represents a different set of assumptions regarding future uptake of electric vehicles.

Reference case scenario

As noted above, the reference case scenario assumes that fuel efficiency for cars and light trucks will improve over time based on the recent federal government regulations. The reference case assumes that few electric vehicles are purchased in any of the communities. This would reflect conditions where electric vehicle prices and performance do not change significantly from 2012 and public charging stations are limited.[15]

In this scenario, changes in air emission levels are driven primarily by fuel efficiency improvements (see section 2.2.1).

EV case scenario

The EV case is based on the same regulatory standards for gasoline or diesel vehicles as the reference case. The difference is the greatly increased number of electric vehicles in the communities, based on assumptions developed by BC Hydro for its draft Integrated Resource Plan. BC Hydro evaluated two estimates of future electric vehicle uptake; the analysis in this report uses the lower of BC Hydro's estimates. In this case, "the percentage of all light duty vehicles on the road (Stock Share) increases from 0.3% in 2017 to 16% in 2031 and to 29% in 2041. The number of B.C. EVs increases from approximately 10,000 in 2017 to over half a million in 2031 to over a million in 2041." [16]

Pembina estimated that to meet these stock shares, approximately 8% of new vehicle purchases in B.C. would need to be electric by 2020, with EVs' share of new vehicle purchases increasing to 45% by 2035. This share of new vehicle sales would lead EVs to comprise approximately 1.4% of vehicle stock in 2020 and 24% of vehicle stock in 2035.

This scenario is within the range of other estimates of future electric vehicle uptake, assuming support for vehicles and charging stations continue. The Community Energy Association reviewed 10 studies on market penetration of EVs and estimated that Metro Vancouver could have 10,000 to 20,000 EVs by 2020, if incentives for vehicle purchases and charging stations are implemented. This represents 0.7% to 1.4% of Metro Vancouver's projected car stock in 2020, similar to the assumptions used in the EV case here.[17] City of Vancouver is aiming to have 15%

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[15] Electric vehicles may be used by car manufacturers to meet the federal regulations, especially after 2020. However, the scope of this report is considering electric vehicle uptake beyond meeting the GHG regulations. Resources were not sufficient to estimate the likely uptake of electric vehicles within the reference case.

[16] BC Hydro, *Draft Integrated Resource Plan,* Appendix 2A, Electric Load Forecast, 2012 http://www.bchydro.com/etc/medialib/internet/documents/planning_regulatory/iep_ltap/2012q2/draft_2012_irp_appendix36.Par.0001.File.DRAFT_2012_IRP_APPX_2A.pdf

[17] Calculation by Pembina based on projected vehicle stock in Metro Vancouver in 2020 being 1,366,028 (personal communication from Community Energy Asssociation on January 10, 2013).

of new vehicle sales be electric vehicles by 2020.[18] The Quebec government has a target of 25% of new vehicles in that province being electric by 2020.[19]

For the modelling by community, we assumed each community would reach approximately the same stock share as the provincial average, assuming all EVs are either battery electric or plug-in hybrid electric vehicles that run almost exclusively on electricity.

2.4 Calibration

The models were calibrated for each community by matching the number of cars and light trucks in the community and the GHG emissions to the information provided in the 2007 Community Energy and Emissions Inventory (CEEI) provided by the Ministry of Environment. Although the 2010 versions of CEEI are now available for viewing, discussions with Ministry of Environment staff indicated that the transportation data are under review and subject to change (as of October 4, 2012) so they recommended using the 2007 CEEI reports.

Table 6. Calibration data

Community	Type of vehicle	Stock (# vehicles)	Average distance travelled (km/vehicle)	Fuel consumption (kilolitres)	Greenhouse gas emissions (tonnes CO_2e)
Campbell River	Cars	8,979	15,537	15,084	36,124
	Light trucks	11,020	19,773	31,769	76,990
Dawson Creek	Cars	2,936	16,861	5,803	13,850
	Light trucks	5,172	20,875	17,067	41,303
Fort St. John	Cars	3,994	17,148	7,938	18,907
	Light trucks	9,694	21,913	32,878	80,030
Peace River RD	Cars	11,183	16,940	22,255	53,090
	Light trucks	26,109	21,295	86,636	211,209
Richmond	Cars	72,035	14,169	108,057	255,980
	Light trucks	37,675	13,767	74,714	178,628

Source: B.C. Ministry of Environment[20]

2.5 Growth rates

Vehicle stock in each community is assumed to grow at 1% per year for the forecast period, based on projections of the provincial growth rate for population for 2010 to 2035.[21]

[18] Sustainability Television. December 13, 2011. *Electric Vehicle charging stations now publicly available in Vancouver* https://www.sustainabilitytelevision.com/news/2439

[19] Province of Quebec, "Electric Vehicles Action Plan," 2012. http://www.vehiculeselectriques.gouv.qc.ca/english/plan-action.asp

[20] B.C. Ministry of Environment, *Community Energy and Emissions Inventory*, 2007. http://www.env.gov.bc.ca/cas/mitigation/ceei/archive_2007/RegionalDistricts/master_index.htm

[21] BCStats, *British Columbia Population Projections 2012-2036*, September 2012. http://www.bcstats.gov.bc.ca/Files/1129fe33-668a-4bab-a8ef-32562eef7e79/BritishColumbiaPopulationProjections2012-2036.pdf

3. Results

3.1 Reference case

The federal government regulations for passenger automobiles and light trucks are expected to significantly reduce fuel consumption and GHG emissions. Table 7 shows the estimated GHG emissions for British Columbia's vehicle stock, based on fuel efficiency improvements included in the regulations (see section 2.2.1). The GHG emissions intensity (grams of CO_2e / kilometre) of the total vehicle stock is expected to decrease by 38% for passenger cars and 40% for light trucks between 2012 and 2035. Note that emissions for electric vehicles are zero, since these values include only vehicle operations.

Table 7. GHG emissions for vehicle operations for stock in B.C. in key years

Vehicle type	Greenhouse gas emissions (g CO_2e/km):			
	2000	2012	2020	2035
Passenger cars	227.6	203.1	200.0	126.6
Light trucks	304.3	275.5	269.3	164.4
Electric vehicles	0.0	0.0	0.0	0.0

3.2 Campbell River

Reaching the EV stock share outlined under Campbell River's EV case scenario would require 371 electric vehicles in the town by 2020 and 8132 electric vehicles by 2035. We assume that these vehicles will be a mix of cars and light-duty trucks.

For simplicity, Pembina assumed that each electric vehicle will be either a full battery-electric or a plug-in hybrid electric running primarily on electricity. The GHG emissions and air pollutants refer to tailpipe emissions. Since electric vehicles emit zero emissions or air pollutants during operation on electricity, the reductions per vehicle are 100% for each kilometre travelled by an EV.

Table 8 and Table 9 show the reductions in GHG emissions and air pollutants due to the increased uptake of electric vehicles in the EV case for Campbell River in 2020 and 2035 respectively.

Table 8. Greenhouse gas emissions and air pollutants from cars and light trucks — Campbell River, 2020

	2020 Results			
	Reference Case	EV case	Savings	Savings %
GHGs (thousand tonnes per year)				
CO_2e	93	92	0.9	**1.0%**
Air pollutants (tonnes per year)				
CO	4,539	4,472	66	**1.5%**
NOx	99	97	1.4	**1.5%**
VOC-Ozone weighted	113	111	1.6	**1.5%**
SOx	2.5	2.5	0.0	**1.5%**
PM	6.3	6.2	0.1	**1.5%**

Table 9. Greenhouse gas emissions and air pollutants from cars and light trucks — Campbell River, 2035

	2035 Results			
	Reference Case	EV case	Savings	Savings %
GHGs (thousand tonnes per year)				
CO_2e	68	55	13	**20%**
Air pollutants (tonnes per year)				
CO	6,021	4,563	1,458	**24%**
NOx	131	99	32	**24%**
VOC-Ozone weighted	150	113	36	**24%**
SOx	1.7	1.3	0.4	**24%**
PM	8.5	6.4	2.1	**24%**

Greenhouse gas emissions

According to estimates by the B.C. Ministry of Environment, Campbell River's cars and light trucks emitted 113 thousand tonnes of GHGs (CO_2e) in 2007.[22] These emissions are expected to decline significantly from 2007 levels, due to federal regulations on cars and light trucks (GHG emissions decline to 93 thousand tonnes in 2020 and 68 thousand tonnes in 2035, in the reference case).

Additional uptake of electric vehicles could lead to further GHG reductions of 0.9 thousand tonnes in 2020 and 13 thousand tonnes in 2035.

[22] B.C. Ministry of Environment, *Community Energy and Emissions Inventory,* 2007, http://www.env.gov.bc.ca/cas/mitigation/ceei/archive_2007/RegionalDistricts/Strathcona/ceei_2007_campbell_river_city.pdf

Air pollutants

Estimates of air pollutants from light-duty vehicles in Campbell River were not available for 2007. Based on output from the GHGenius model,[23] only negligible reductions in air pollutants are expected per kilometre for light-duty vehicles in the reference case. The total kilometres will increase due to assumed increase in the number of vehicles in the community over time.

In the EV case, the reductions are 1.5% in 2020 and 24% in 2035, relative to the reference case in those years.

3.3 Peace Region

Reaching the EV stock share outlined under the Peace region's EV case scenario would require 733 electric vehicles in the region by 2020 and 16,150 electric vehicles by 2035. We assume that these vehicles will be a mix of cars and light-duty trucks.

For simplicity, Pembina assumed that each electric vehicle will be either a full battery-electric or a plug-in hybrid electric running primarily on electricity. The GHG emissions and air pollutants refer to tailpipe emissions. Since electric vehicles emit zero emissions or air pollutants during operation on electricity, the reductions per vehicle are 100% for each kilometre travelled by an EV.

Table 8 and Table 9 show the reductions in GHG emissions and air pollutants due to the increased uptake of electric vehicles in the EV case for the Peace region in 2020 and 2035 respectively.

Table 10. Greenhouse gas emissions and air pollutants from cars and light trucks — Peace region, 2020

	2020 Results			
	Reference Case	EV case	Savings	Savings %
GHGs (thousand tonnes per year)				
CO_2e	210	208	2	**1.0%**
Air pollutants (tonnes per year)				
CO	9,698	9,553	146	**1.5%**
NOx	211	208	3.2	**1.5%**
VOC-Ozone weighted	241	237	3.6	**1.5%**
SOx	5.4	5.3	0.1	**1.5%**
PM	13.4	13.2	0.2	**1.5%**

[23] See http://www.ghgenius.ca/

Table 11. Greenhouse gas emissions and air pollutants from cars and light trucks — Peace region, 2035

	2035 Results			
	Reference Case	EV case	Savings	Savings %
GHGs (thousand tonnes per year)				
CO_2e	152	122	30	**20%**
Air pollutants (tonnes per year)				
CO	13,086	9,869	3,216	**25%**
NOx	285	215	70	**25%**
VOC-Ozone weighted	325	245	80	**25%**
SOx	4	3	1	**25%**
PM	18	14	5	**25%**

Greenhouse gas emissions

According to estimates by the B.C. Ministry of Environment, the Peace region's cars and light trucks emitted 264 thousand tonnes of GHGs (CO_2e) in 2007.[24] These emissions are expected to decline significantly from 2007 levels, even without the uptake of electric vehicles, due to federal regulations on cars and light trucks (GHG emissions decline to 210 thousand tonnes in 2020 and 152 thousand tonnes in 2035, in the reference case).

Additional uptake of electric vehicles could lead to further GHG reductions of 2 thousand tonnes in 2020 and 30 thousand tonnes in 2035.

Air pollutants

Estimates of air pollutants from light-duty vehicles in the Peace region were not available for 2007. Based on output from the GHGenius model,[25] only negligible reductions in air pollutants are expected per kilometre for light-duty vehicles in the reference case. The total kilometres will increase due to assumed increase in the number of vehicles in the community over time.

In the EV case, the reductions are 1.5% in 2020 and 25% in 2035, relative to the reference case in those years.

3.4 Richmond

Reaching the EV stock share outlined under Richmond's EV case scenario would require 1865 electric vehicles in the city by 2020 and 40,567 electric vehicles by 2035. We assume that these vehicles will be a mix of cars and light-duty trucks.

[24] B.C. Ministry of Environment, *Community Energy and Emissions Inventory,* 2007.

[25] See http://www.ghgenius.ca/

For simplicity, Pembina assumed that each electric vehicle will be either a full battery-electric or a plug-in hybrid electric running primarily on electricity.[26] The GHG emissions and air pollutants refer to tailpipe emissions. Since electric vehicles emit zero emissions or air pollutants during operation on electricity, the reductions per vehicle are 100% for each kilometre travelled by an EV.

Table 8 and Table 9 show the reductions in GHG emissions and air pollutants due to the increased uptake of electric vehicles in the EV case for Campbell River in 2020 and 2035 respectively.

Table 12. Greenhouse gas emissions and air pollutants from cars and light trucks — Richmond, 2020

	2020 Results			
	Reference Case	**EV case**	**Savings**	**Savings %**
GHGs (thousand tonnes per year)				
CO_2e	354	351	3	**0.9%**
Air pollutants (tonnes per year)				
CO	18,585	18,330	256	**1.4%**
NOx	404	398	5.6	**1.4%**
VOC-Ozone weighted	462	456	6.4	**1.4%**
SOx	10.3	10.1	0.1	**1.4%**
PM	25.7	25.3	0.4	**1.4%**

Table 13. Greenhouse gas emissions and air pollutants from cars and light trucks — Richmond, 2035

	2035 Results			
	Reference Case	**EV case**	**Savings**	**Savings %**
GHGs (thousand tonnes per year)				
CO_2e	249	204	45	**18%**
Air pollutants (tonnes per year)				
CO	23,749	18,194	5,556	**23.4%**
NOx	516	396	121	**23.4%**
VOC-Ozone weighted	590	452	138	**23.4%**
SOx	7	5	2	**23.4%**
PM	34	26	8	**23.4%**

[26] Analysis based on mix of battery electric and plug-in hybrid electric vehicles will be available in forthcoming Pembina report, *Clean Air Impacts of Electric Vehicles.*

Greenhouse gas emissions

According to estimates by the B.C. Ministry of Environment, Richmond's cars and light trucks emitted 434 thousand tonnes of GHGs (CO_2e) in 2007.[27] These emissions are expected to decline significantly from 2007 levels, even without the uptake of electric vehicles, due to federal regulations on cars and light trucks (GHG emissions decline to 354 thousand tonnes in 2020 and 249 thousand tonnes in 2035, in the reference case).

Additional uptake of electric vehicles could lead to further GHG reductions of 3 thousand tonnes in 2020 and 45 thousand tonnes in 2035.

Air pollutants

Estimates of air pollutants from light-duty vehicles in Richmond were not available for 2007. Based on output from the GHGenius model,[28] only negligible reductions in air pollutants are expected per kilometre for light-duty vehicles in the reference case. The total kilometres will increase due to assumed increase in the number of vehicles in the community over time.

In the EV case, the reductions for air pollutants are 1.4% in 2020 and 23.4% in 2035, relative to the reference case in those years.

3.5 Overall comments

3.5.1 Key results

Electric vehicles will lead to reductions in GHG and air pollutant emissions in the communities evaluated. Overall reductions of about 1% in both greenhouse gas emissions and air pollutants from passenger vehicles and light truck could be expected by 2020, based on sales of new EVs growing to 10% of all sales by 2020.

Much higher reductions, up to 25%, could occur by 2035, assuming sales of EVs continue to grow significantly.

Reductions are relative to reference case pollution levels for passenger cars and light trucks in that year.

The combination of increased fuel efficiency due to Canadian regulations for passenger vehicles plus more electric vehicles will allow communities in British Columbia to significantly reduce greenhouse gas emissions relative to 2007 levels.

3.5.2 Key assumptions and caveats

The modeling in this analysis is based on simplifying assumptions. The following assumptions would benefit from additional research if resources are available.

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[27] B.C. Ministry of Environment, *Community Energy and Emissions Inventory*, 2007.

[28] See http://www.ghgenius.ca/

In the reference case, the estimated uptake of electric vehicles in British Columbia due to the federal GHG regulations for light duty vehicles is not specified but assumed low. Further research on the likely sales impact in Canada and by province will be useful to provide a full picture of electric vehicle uptake.

It is assumed that emissions per kilometre of local air pollutants (CO, NOx, SO2, VOC, and PM) do not change over time in the reference case. This assumption, based on output from the GHGenius model, could be tested more thoroughly with greater research resources.

The EV case assumes that by 2035 almost half of new car buyers will be buying electric vehicles: 45% of passenger cars and light trucks will be electric. The performance of future EVs will need to continuously improve in order to meet this fraction of new vehicle sales.

The assumption that the electric vehicles in the EV scenario will primarily be either battery electric or plug in hybrid electric vehicles running primarily on electricity leads to higher emissions savings than if it is assumed a high uptake of plug in hybrid electric running significantly on gasoline. Again the performance of electric vehicles will need to improve and / or be supplemented by government policies to encourage this pattern.

This analysis assumes that travel behaviour in the future will be similar to current behaviour. In particular the estimates are based on similar number of vehicles per population and kilometres traveled per vehicle.

3.5.3 Life cycle emissions

To check the overall impact of EVs, Pembina also considered life cycle emissions, covering upstream fuel production and distribution as well as vehicle material and assembly. This analysis, based on results of the GHGenius model, demonstrated the overall emissions are lower for EVs than for gasoline vehicles: GHGs are reduced by approximately 82% over the lifetime of an EV, compared to a gasoline vehicle. Local air pollutants were reduced by 36% for PM, 45% for SOx, 96% for VOCs, 81% for NOx and 99% for CO. See Appendix A for charts demonstrating these results.

4. Next steps and recommendations

This research shows that EVs can contribute to reducing GHGs and local air pollutants in B.C. communities. The reductions are modest in 2020 but would grow over time.

Reaching the environmental benefits identified in this report will require additional actions to support electric vehicles. Auto manufacturers and battery developers are striving to produce EVs with lower capital costs and a wider range of performance features. The public sector can also support EVs through policies and incentives.

Many communities in B.C. have taken steps to reduce barriers to EVs by citizens, businesses and visitors. In particular, 562 EV charging stations that are accessible to the public have been installed or are planned throughout the province. A portion of the funding for these stations was provided by the provincial government.[29] The province of British Columbia also provides financial incentives for purchases of EVs and charging stations for private use.[30]

Additional actions by local governments to support electric vehicles include:

- Provide information for residents and businesses – share information on benefits and performance of EVs through handouts at municipal hall and on website
- Provide EV demonstration opportunities – link with existing municipal events, and invite automotive dealers to participate. Include EVs in commuter challenges (what is the fastest and lowest GHG option to get to work)
- Work with businesses to identify and reduce barriers to installing charging stations that are available to the public
- Support car-sharing organizations that are interested in EVs. Municipal governments can consider joint purchase (with priority to staff during working hours) and provide parking spots at city hall. For example, the City of Vancouver has an arrangement with Modo with an EV available to car-share members.[31]
- Consider reducing development cost charges for new developments that include EV charging stations
- Install signs and participate in websites that identify locations of public charging stations in the community
- Market the municipality for its environmental leadership, including supportive actions for EVs.

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[29] Government of British Columbia, “B.C. plugging in to electric vehicle fast chargers,” media release, January 17, 2013. http://www2.news.gov.bc.ca/news_releases_2009-2013/2013ENV0002-000067.htm. Government of British Columbia, “B.C. businesses embrace clean car infrastructure,” media release, December 6, 2012. http://www.newsroom.gov.bc.ca/2012/12/bc-businesses-embrace-clean-car-infrastructure.html

[30] For more information see LiveSmart BC, "Transportation Rebates and Incentives." http://www.livesmartbc.ca/incentives/transportation/

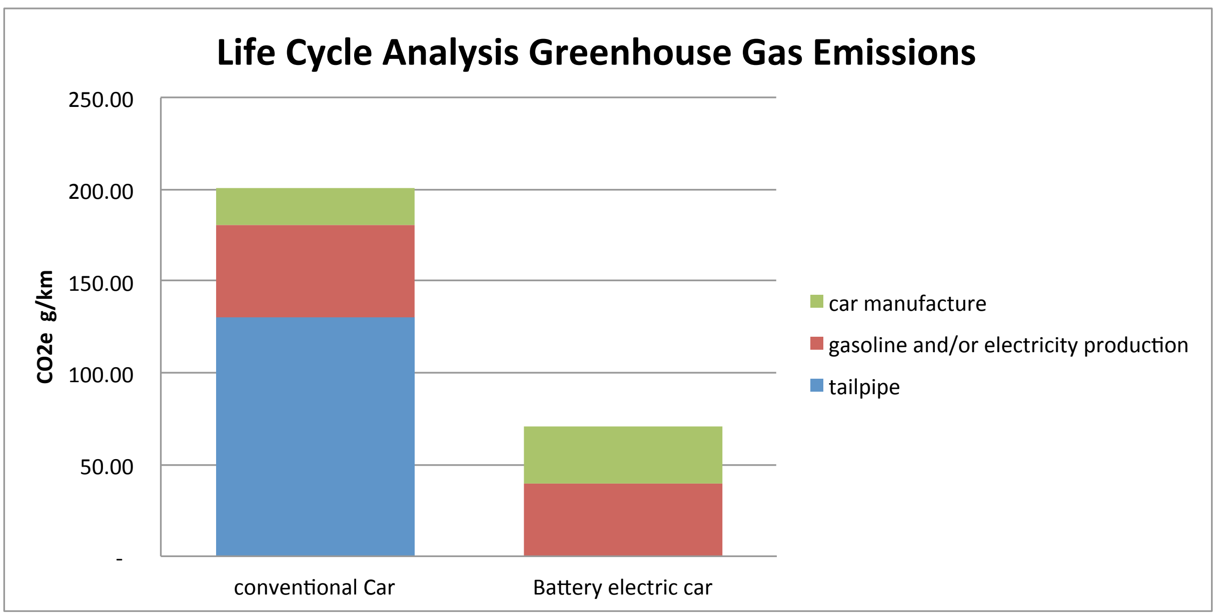
[31] Canada Newswire. “Modo adds more electric juice with a fully electric vehicle,” November 1, 2011. http://www.newswire.ca/en/story/869237/modo-adds-more-electric-juice-with-a-fully-electric-vehicle

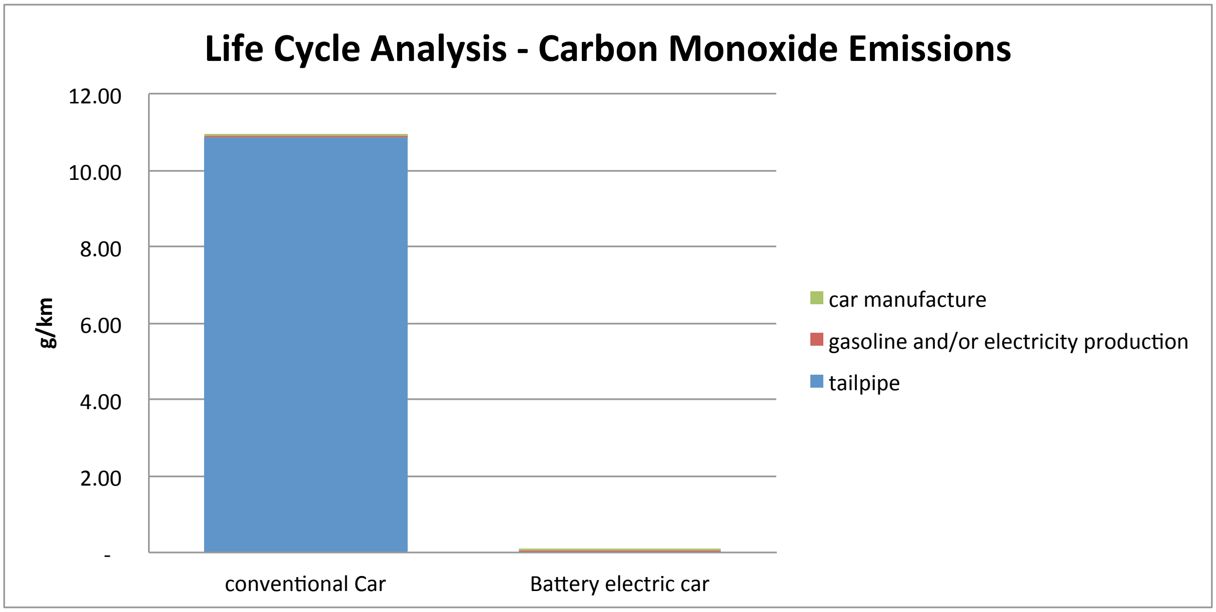
EVs are only part of the solution. Most communities will need to also consider other initiatives in order to meet their climate and clean air objectives. Municipalities in B.C. are encouraged to explore opportunities to strive for the cleanest transportation for their communities such as reducing the need for long-distance travel by personal vehicles, encouraging walking and cycling, and when necessary, using the least polluting vehicles.

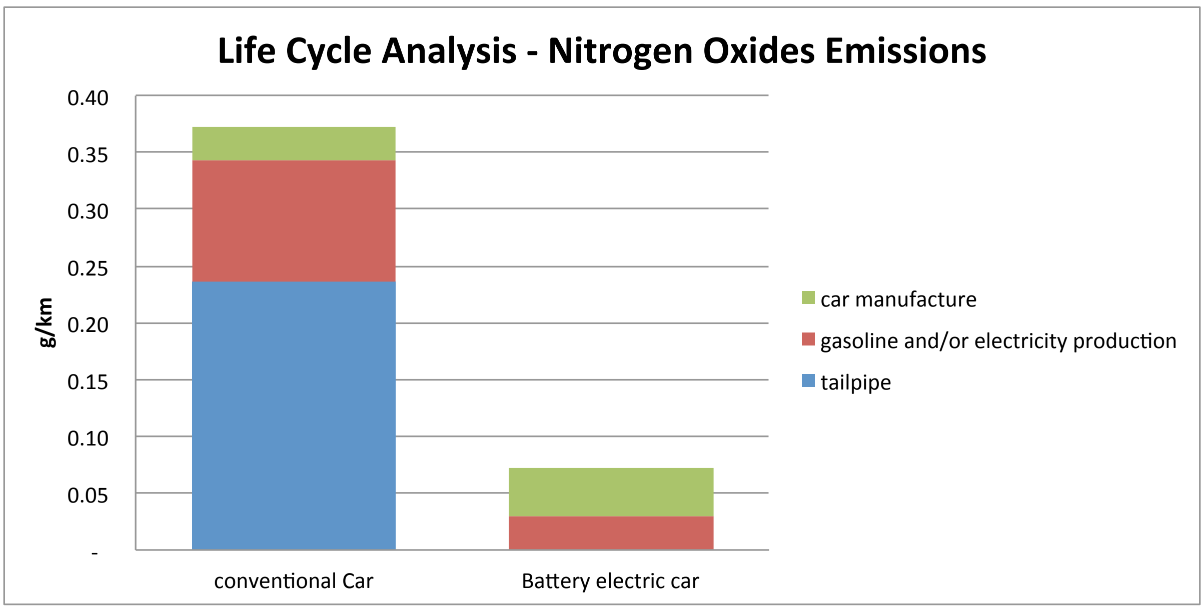
Appendix A. Life Cycle Analysis

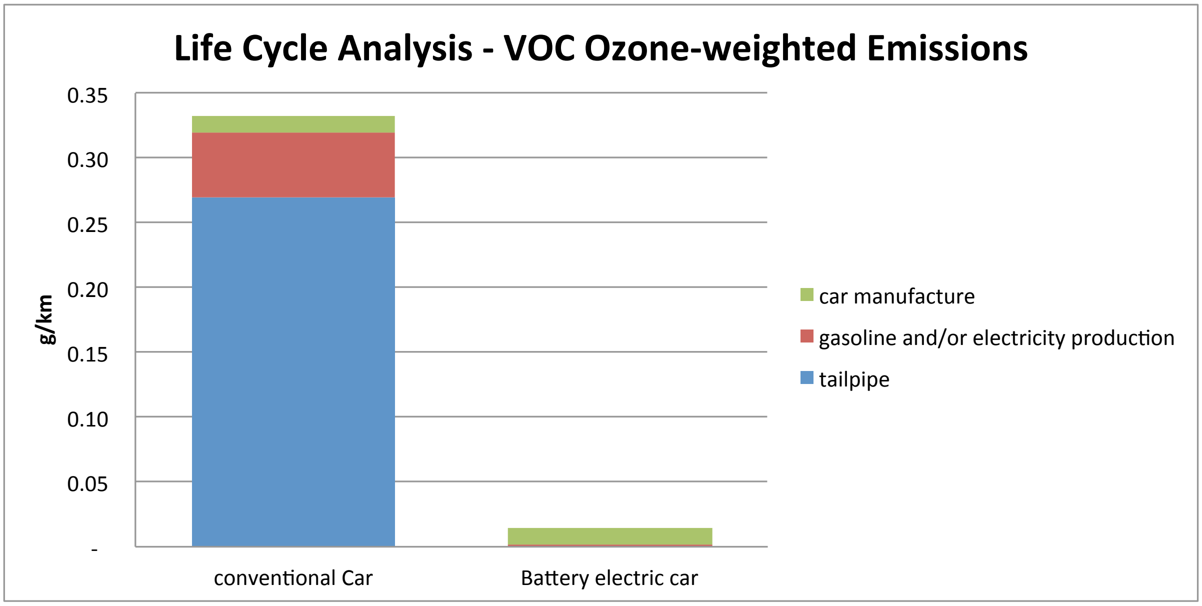
To check the overall impact of EVs, Pembina also considered life cycle emissions, covering upstream fuel production and distribution as well as vehicle material and assembly. This analysis, based on results of the GHGenius model, demonstrated the overall emissions are lower for EVs than for gasoline vehicles: GHGs are reduced by approximately 82% over the lifetime of an EV, compared to a gasoline vehicle. Local air pollutants were reduced by 36% for PM, 45% for SOx, 96% for VOCs, 81% for NOx and 99% for CO.

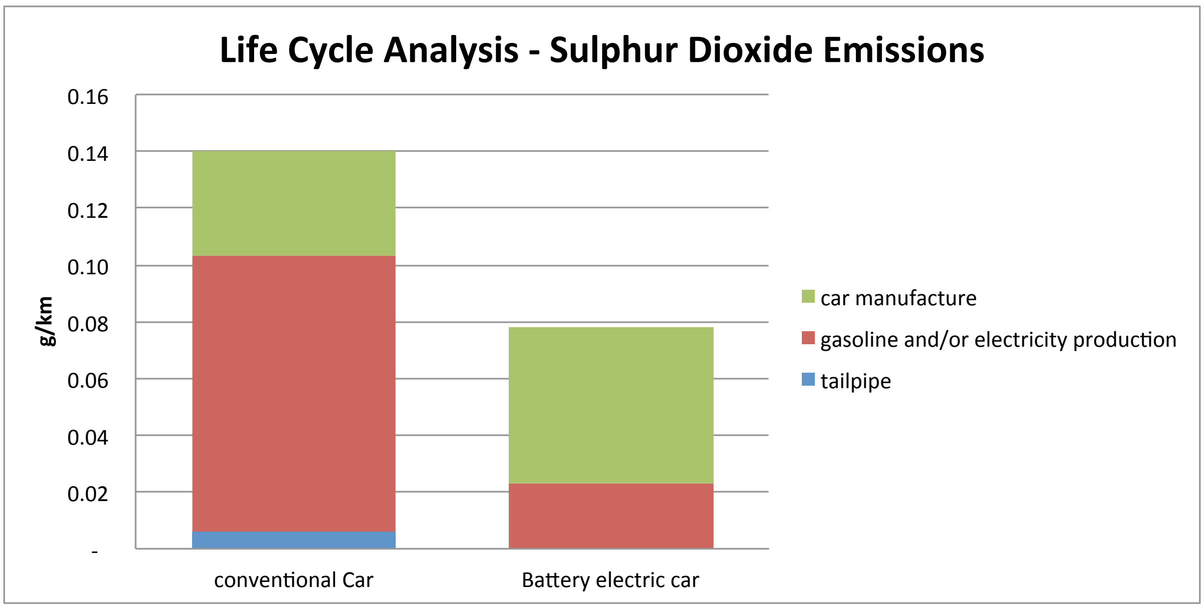
The following figures show the emissions for vehicle manufacture, gasoline and/or electricity production and tailpipe for conventional vehicles and battery electric vehicles for GHG emissions and the five air pollutants. The results are for vehicle model year 2020, as an example; other years have similar patterns. Note that the scale of the y-axis changes for each chart.

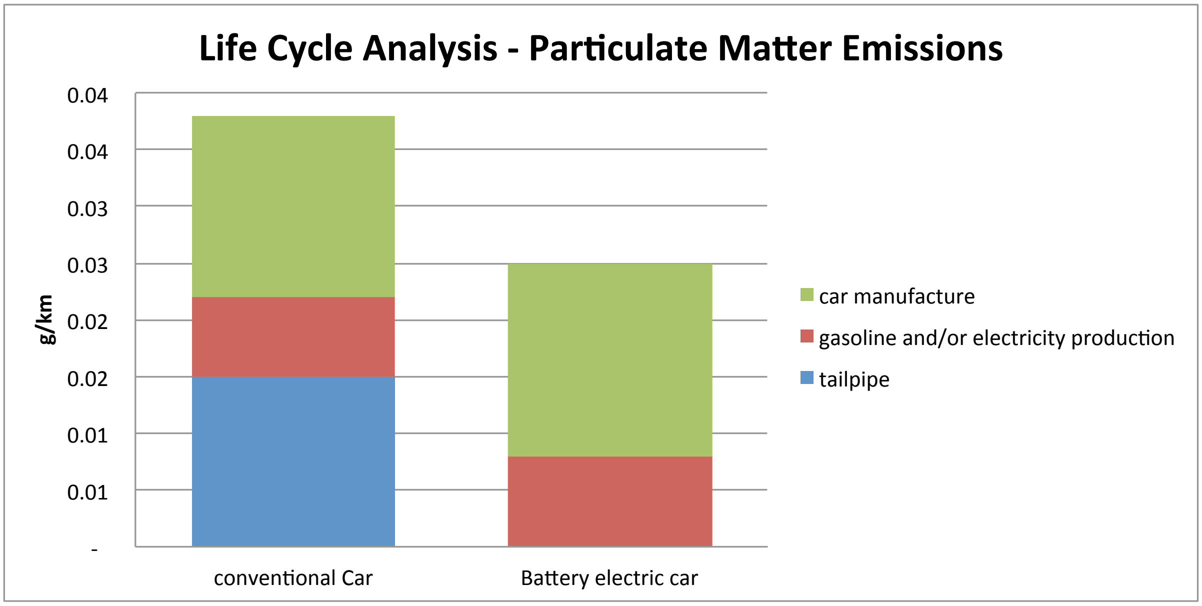



Life Cycle Analysis - Carbon Monoxide Emissions
12.00
10.00
8.00
6.00
4.00
2.00
-
g/km
conventional Car
Battery electric car
car manufacture
gasoline and/or electricity production
tailpipe


Life Cycle Analysis - Nitrogen Oxides Emissions
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
-
g/km
conventional Car
Battery electric car
car manufacture
gasoline and/or electricity production
tailpipe


Life Cycle Analysis - VOC Ozone-weighted Emissions
g/km
0.35
0.30
0.25
0.20
0.15
0.10
0.05
-
conventional Car
Battery electric car
car manufacture
gasoline and/or electricity production
tailpipe


Life Cycle Analysis - Sulphur Dioxide Emissions
g/km
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
-
conventional Car
Battery electric car
car manufacture
gasoline and/or electricity production
tailpipe


Life Cycle Analysis - Particulate Matter Emissions
0.04
0.04
0.03
0.03
0.02
0.02
0.01
0.01
-
g/km
conventional Car
Battery electric car
car manufacture
gasoline and/or electricity production
tailpipe

Appendix B. Caveats

Several caveats should be considered regarding the results of this report.

Model choice

The model used for estimating the air pollutants from gasoline vehicles is GHGenius, as described in section 2.2.2. This model was chosen among several options based on access to model (available free as a download) and match of input needs for the model with data available for communities (GHGenius has BC-specific default values and does not require data on the mix of age of vehicle stock by community). GHGenius owned and managed by Natural Resources Canada[32] and is used for calculations in British Columbia's Low Carbon Fuel Requirements Regulation[33].

The air pollutants values for vehicle operation in GHGenius are based output from Mobile 6.2, a model developed by the US EPA. The output of GHGenius reflects that average emissions per year of future model years of vehicles over their lifetimes by running Mobile 6.2 hundreds of times to get average rates for each model year.[34] This allows the GHGenius user to input particular model years of interest, and have the model output reflect the multiple runs that would have been required from Mobile 6.2, based on the averages as estimated by GHGenius developers. These averages may not precisely reflect each B.C. community mix of vehicles now and in the future. However, developing detailed estimates of current and future vehicles inventories for each community was beyond the resources of this research.

Mobile 6.2 has recently been significantly changed and the model is now called MOVES, Motor Vehicle Emission Stimulator.[35] GHGenius has not yet incorporated these updates. Thus the use of GHGenius for this research rather than MOVES reflects older data and calculation approaches for the air pollutants.

For the research in this report, the strong relationship between age of vehicle and emissions is captured in the average emissions output of GHGenius, rather than by projecting and tracking the mix of ages of the car stock over time for each community. At this point, CEEI reports do not provide age of vehicles and attempting to estimate the ages in the future vehicle stock of the communities would require significant assumptions that we could not develop with our resources.

The research will benefit from revisions once either GHGenius has been updated to MOVES or resources are available in B.C. to (i) collect more detailed data on vehicle types and ages for each community, (ii) project changes in vehicle age mix over time and (iii) run MOVES based on this data.

GHG regulations for Cars and Light Trucks

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[32] http://www.ghgenius.ca/about.php

[33] http://www.em.gov.bc.ca/RET/RLCFRR/FAQ/Pages/default.aspx#14b

[34] Don O'Connor, personal communication, August 15, 2012.

[35] http://www.epa.gov/otaq/models/moves/index.htm

The following simplifying assumptions were used to simulate the federal GHG regulations

- It is assumed that the GHG emissions intensities (g/km) in the regulations will be reflected in "on the road" fuel efficiency. Fuel efficiency may be reduced due to driving behaviour or poor maintenance, but the extent of these factors has not been accounted for in this research
- The regulations include a few options that provide manufacturers with flexibilities to meet the regulations. This research assumes that the use of any flexibilities does not significantly reduce the GHG emissions intensity of the regulations.
- Car manufacturers would count the purchases of electric vehicles as contributing to meeting the GHG regulations on a national basis. This research assumes that the additional uptake of electric vehicles in the EV scenario is above the national average needed to meet the GHG regulations.

The first two assumptions could lead to under-estimates of the GHG emission reductions while the third assumption could lead to an over-estimate of GHG emissions reductions. We are unable to quantify the size of the over and under-estimates at this time.

Electric Vehicles uptake

This variable has the greatest uncertainty for the reseach – how many electric vehicles will be bought to meet the GHG regulation and personal preferences? And how many will be purchased base on additional actions by municipal and provincial governments? This research has focused on the air emissions from the vehicles, rather than on the consumer behaviour research. As additional consumer behaviour research becomes available in public domain, the research in this report can be updated to better reflect the new findings.

CEEI 2010 updates

The CEEI reports for 2010 were under-going revisions while this research was underway. These CEEI revisions were completed prior to publishing this report but the modeling for the communities had already been completed and analyzed. Pembina did not have the resources to re-do the modeling at that point.