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Backgrounder

Electric Vehicles

Powering the Future

by Jeremy Moorhouse and Katie Laufenberg

Why your next car might be electric

British Columbia could be home to between one and 1.3 million electric vehicles by 2030 — one of the highest electric vehicle adoption rates in North America.[1] If that many electric vehicles were on the province's roads right now, oil demand would be reduced by about 12 million barrels per year — more than twice the amount of oil spilled in the Gulf of Mexico during BP's Deepwater Horizon disaster — and B.C.'s annual greenhouse gas emissions would be reduced by seven per cent, or 4.7 million tonnes.[2]

Why is everyone talking about electric vehicles?

The term "electric vehicle" can apply to a battery electric vehicle, a plug-in hybrid — or even a hydrogen fuel cell electric vehicle. In this backgrounder, we focus on plug-in electric vehicles. Electric vehicles (EVs) are designed to be powered, in whole or in part, by electricity from the power grid. There are two categories of EVs. A battery EV is solely powered by batteries, while a plug-in hybrid EV can run on electricity, fuel or a combination of the two. EVs have been a hot topic in the past few years as technology has improved and the search for climate change solutions has accelerated. The Lower Mainland of British Columbia has been a hot bed of discussion and activity around EVs. B.C. is one of the most promising places in North America for their adoption because of five key reasons:

1. Electrifying B.C.'s transportation would significantly reduce the province's greenhouse gas (GHG) emissions.
    - **Current transport by fossil fuels is dirty—** Personal transportation accounts for 14% of GHG emissions in the province. In an average B.C. household, almost half (45.3%) of emissions come from personal cars and trucks.[3]
    - **B.C. is committed to clean electricity—** The province is currently producing about 93% of its electricity from clean or renewable resources with plans to have all remaining GHG emissions offset by 2016.[4] Electricity generation from renewable sources has other

environmental impacts, but these can be minimized if new projects are well planned and regulated.

2. B.C. has the most ambitious carbon tax in North America, which will make EVs powered by renewable energy increasingly affordable as the tax increases over time.[5]
3. B.C.'s population is largely concentrated in urban areas (73%) and 95% of all car trips are less than 30 km.[6]
4. British Columbians have switched to hybrid vehicles at double the rate of the Canadian average.[7]
5. B.C. has local governments highly supportive of EV adoption:
   - **Vancouver building by-laws —** The city of Vancouver has required dedicated EV charging circuits in all new single detached homes since 2008 and in 20% of parking stalls in multi-unit residential buildings and off-street bike parking since 2009.[8]
   - **Local governments are interested —** Many local B.C. governments have included EV goals in their community environmental plans and are participating in an EV community advisory group organized by the province[9].
   - **Agreements with major automakers —** The City of Vancouver has been actively encouraging automakers to bring their EVs to the Lower Mainland as soon as possible. Agreements have been struck with Toyota, Nissan and Mitsubishi.[10]
   - **Project Get Ready —** The British Columbia Institute of Technology (BCIT) has joined forces with the City of Vancouver and the Rocky Mountain Institute to help Lower Mainland communities prepare for the use of EVs. Project Get Ready Vancouver will see BCIT champion the development of a five-year plan of action aimed at making the Lower Mainland EV ready.[11]

What's In A Name?

With battery and plug-in hybrid EVs coming to market around the same time, many people may be confused by the new terminology.

Battery Electric Vehicle: A battery electric vehicle runs entirely on an electric motor, powered by a battery. The battery is charged through an electrical outlet. The Nissan Leaf is a battery electric vehicle being released in Vancouver in January 2011. The Leaf will have a range of 160 km and reach speeds of 140 km/h.

Plug-In Hybrid Electric Vehicle: A plug-in hybrid vehicle has both an electric motor and a gasoline engine onboard. These vehicles generally run on the electric motor until the battery is depleted, at which point the gas engine can kick in, extending the car's range. The main battery in a plug-in hybrid is charged through an electrical outlet. An example of a plug-in hybrid is the Chevrolet Volt.

Hybrid Electric Vehicle: A typical hybrid electric vehicle is fuelled by gasoline and uses a battery-powered motor to improve efficiency, thus is not considered a plug-in electric vehicle. The battery in a gasoline hybrid is never plugged into an electrical outlet, but instead is powered by a combination of the gasoline engine and regenerative braking. The most well-known hybrid electric vehicle is the Toyota Prius.

How practical is an electric vehicle for my home or business?

Before deciding to purchase an EV, consumers will want to know the answers to a few questions: How far can I drive an EV? Where can I recharge it? How much does it cost?

How far can I drive an EV?

According to 2006 Statistics Canada data, the median commuting distance in Metro Vancouver is about 15 kilometres round-trip.[12] The ranges of EVs vary, depending on the model. The Chevy Volt, a plug-in hybrid electric, will drive 65 kilometres on battery power before switching to its gasoline engine, allowing 600 km total range before you need to either find an outlet or a gas station.

The Nissan Leaf and the Tesla Roadster, both battery electrics, will drive 160 km and 320 km respectively on battery power before they need charging.[13]

For drivers who frequently need a vehicle with extended range, plug-in hybrid EVs will likely be more popular at first. For those who just need a car for city driving, battery electrics will be a good fit. Some families may choose to have a battery electric vehicle to meet the majority of their day-to-day needs and to rent a vehicle for road trips.

As charging infrastructure and battery technology improves, battery electric vehicles will become increasingly practical. Quick charging stations at gas stations and malls will be able to fully charge a battery electric vehicle in just 30 minutes, for example. By 2015, the second generation of EVs are expected to hit the market with double the range of the first EVs to come to market in 2011.

Advancements are anticipated in battery technology due to the U.S. Department of Energy's injection of US$5 billion of stimulus funding for EVs. This should result in more affordable, mainstream electric cars in North America. Battery costs are expected to decrease by nearly 70% by the end of 2015. Since batteries are the most expensive component of EVs, this will reduce cost significantly.

Table 1 below shows the yearly expected price of an EV battery with 160-kilometre range and output of 4.8 kilometres per kWh (comparable to the Nissan Leaf).

Year	Expected Price of EV battery
2009	$33,000
2013	$16,000
2015	$10,000
2020	$5,000

Table 1. Expected price of EV batteries through 2020.

Source: US DOE (2010) The Recovery Act: Transforming America's Transportation Sector, Batteries and Electric Vehicles[14]

Where can I recharge my EV?

BC Hydro is preparing to become a major transportation fuel provider and is working with the auto industry to prepare the province's electrical infrastructure for a seamless transition to EVs.[15]

To charge an EV you must plug it into an electrical outlet. Recharge time depends on the size of the car's battery and the power source it's plugged into. A typical household outlet (120 volt) will fully recharge a battery in between six and 16 hours, depending on the car. A 240-volt outlet, such as the one you plug a clothes dryer into, will recharge a battery in half that time (three to eight hours). These options are relatively accessible to home owners, but they are not necessarily so accessible to people living in apartments or condos. This highlights the importance of municipal leadership, as displayed by the City of Vancouver in requiring all new homes and 20% of parking stalls in mulit-unit residential buildings to have EV charging outlets.

In the meantime, public charging stations are expected to help fill the gap. EasyPark parkades in Vancouver are adding charging stations for EV drivers away from home, while car sharing programs that include EVs would manage charging logistics with a dedicated parking spot.

Vancouver company Rapid Electric Vehicles (REV) and electrical contractor Viridian Power have announced a partnership to install and maintain Coulomb Technologies Inc.'s chargepoints in major cities across Canada by 2012[16]. A live map and iPhone app will show drivers available chargepoint locations.[17]

In North America, shopping malls, gas stations and other vehicle destinations are beginning to install an even higher voltage charging station that delivers between 400 and 480 volts of power and can fully charge the Nissan Leaf, for example, in about 30 minutes. These chargers have not been standardized yet, but they will likely charge a fee and be placed in strategic locations to alleviate range anxiety. North America's first quick charger was recently installed in downtown Portland, Ore., another active region in EV adoption[18]. Vancouver is about to unveil its first rapid charger, which can recharge a battery to 80% in twenty to thirty minutes, at Science World.[19]

How much will an EV cost?

The up-front cost of an plug-in vehicle is between $4,000 and $13,000 more than an equivalent car with an internal combustion engine[20]. While the price tag is higher it is important to recognize that the cost of driving an EV is significantly less than the cost to fuel a gasoline vehicle. At current energy prices an average car owner in B.C. would save about seven cents per kilometer, or $1,200 per year, if they switched to an EV.[21]

The Rocky Mountain Institute has developed a calculator[22] that allows consumers to compare the cost of purchasing and fuelling an EV compared to a conventional vehicle or hybrid electric.

The cost of all energy sources can be expected to increase for a variety of reasons, but the price difference between clean and dirty energy sources will continue to grow in B.C. as the carbon tax increases over time. This is the advantage of driving an EV in B.C., where most of our electricity is supplied by a renewable source and where a provincial carbon tax on dirty energy exists.

EVs as fleet vehicles

Fleet vehicles are ideal candidates for electrification given their consistent driving demands, high annual mileage and defined routes. In fact, most prototype EVs are first tested in fleets before they are perfected for consumer sale. The City of Vancouver, BC Hydro, Novex and Purolator all currently have fleet EVs and Canadian companies Azure Dynamics[23] and Rapid Electric Vehicles[24] offer fleet-specific electric vans and SUVs for commercial use.

Just as we've seen taxi operators move to hybrid electric vehicles due to fuel savings, it will make sense for many fleets to go electric. Because fleet vehicles tend to rack up a lot of kilometres, fuel savings are especially significant.

As a fleet operator, the cost of installing charging stations can be offset by charging the public a fee for using them during the day. You can then charge your own fleet overnight, during off-peak time. It is also common for loading docks to already have electricial outlets available.

Local EV fleet provider Rapid Electric Vehicles offers a handy return on investment calculator on its website to help fleet managers calculate the cost savings possible through electrification.[25] Large fleets may also be able to negotiate lower off-peak charging rates in return for agreed "black out" charging times with their utility. EV buyers clubs, such as Toronto Atmospheric Fund's EV300[26] group, help leverage the purchasing power of a number of fleets and facilitate information sharing among fleet managers. Green Fleets BC[27] is currently looking for B.C. business owners interested in purchasing EVs for their fleets, so manufacturers will recognize B.C. as an attractive market and offer the group discounted prices for bulk purchases.

Electric fleets could be moneymakers

Vehicle-to-Grid (V2G) technology is rapidly evolving and involves the communication and transfer of electricity between EVs and the electricity grid. This technology is highly valuable to grid operators that could potentially use the power from millions of charging EVs to meet peak demand. It can also be valuable to fleet operators. An investigation of revenue from the sale of power for grid regulation in four US power markets was undertaken by Tomic and Kempton[28]. They estimated that a fleet of 100 Think City vehicles (www.think.no) could generate a net profit of US $7,000-$70,000 and remain profitable in all power jurisdictions studied while increasing the stability of the grid.[29]

How much electricity will be required to charge electric vehicles in the next 20 years?

Electrifying our personal and fleet transporation is a big switch of energy providers, and it isn't going to happen overnight. The most common question is: can our current electricity system handle a massive influx of EVs?

Using a recharge estimate of 13 kWh[30] per day per vehicle, unused overnight electricity capacity in B.C. could charge nearly 2.4 million light duty vehicles in the winter and more than 8.8 million vehicles in the summer, when there is much more spare capacity.[31] Since there are about 2.5 million registered light duty vehicles in B.C. today, it is clear we won't see this type of market penetration for many years, but this analysis (by the Pacific Institute for Climate Solutions) illustrates that on the whole there are no immediate threats to the grid from EVs that avoid charging during peak demand.

If all passenger vehicles currently in B.C. switched to electric plug-in vehicles, the increase on BC Hydro's load would be approximately 15% or 9,000 GWh per year[32]. Fortunately, the adoption of electric vehicles will be much more gradual than that. The bottom line is that the increased electricity demands of EVs can be managed.

Consumers should expect communication from BC Hydro while the utility figures out where EVs owners are charging, to avoid any local distribution interruptions. For example, the City of Vancouver recently set up a website[33] for consumers interested in EVs to learn more about the vehicles coming to market and to participate in a survey. This will help the city and BC Hydro to identify where high-adoption neighbourhoods are located and will also allow the region to show automakers that there is a viable market in the Lower Mainland for electric cars.

A closer look

Power requirements: The power load of a recharging EV is equivalent to about four plasma televisions, and a homeowner can expect to use 0.2 kWh of electricity per kilometre driven.[34]
Adoption rates: According to a 2009 presentation by BC Hydro, British Columbia is expected to have between 25,000 and 32,000 EVs on the road by 2013. By 2030 that number will reach between one and 1.3 million. These numbers include both plug-in hybrid and battery electric vehicles and assume an average conventional vehicle life of 15 years and an EV life of 10 years.[35]
High-adoption areas: EV adoption and home EV charging will likely be geographically clustered in areas where current hybrid owners live, known in the industry as "Prius Clusters." It's interesting to note that during the pre-order period for the Nissan Leaf battery EV, half of all down payments in the U.S. came from a household with a Toyota Prius[36]. High-adoption areas in B.C. are expected to have 5% EVs by 2015 and more than 50% by 2030.
More electricity needed: In the long term EV use will affect generation and transmission and require an additional 4,000 GWh of additional energy generation by 2030.
Local grid impact: The most pressing issues for the grid controller are the distribution transformers and substations that will need to be upgraded to handle the anticipated EV charging load in the cluster areas. There is a risk of increased transformer failures and requirement for substation capacity expansions[37], but these types of upgrades are common for utilities as they adjust for new consumer electronics, such as plasma TVs.[38]

A smarter grid[39]

Large-scale EV adoption can also have positive impacts on the electricity grid. Often, renewable electricity resources such as wind and solar are intermittent and unpredictable, making it difficult to supply electricity during periods of high demand. EVs can potentially make wind and solar more attractive to electricity utilities because they can act as storage devices to accept power from wind and solar projects when they are plugged in. This concept, known as Vehicle-to-Grid (V2G) technology is currently in research phase at institutions such as BCIT, but will someday increase the grid's reliability because energy transfers would be controlled by the grid operator. Other researchers are currently exploring the feasibility of repurposing EV batteries at the end of their useful life in mobility. In this scheme, when vehicle batteries reach a certain age and can no longer hold a significant charge (~75%), the batteries would be sold to electricity utilties as power storage for renewable energy projects such as wind and solar.

Is driving an electric vehicle better for the environment?

As mentioned in the introduction, bringing a million EVs to B.C.'s roads right now would reduce oil demand by approximately 12 million barrels per year.[40] It's easy to get caught up in statistics like this, but determining whether an EV is more environmentally responsible than a gasoline vehicle is a complicated task requiring assessing the full life cycle of a vehicle, while considering many assumptions.

How does a vehicle have an impact on the environment?

All aspects of a vehicle's production, operation and disposal create some impact on the environment. Analyzing the manufacturing, operating and disposing of a vehicle is known as life-cycle assessment (LCA). This approach is necessary when comparing vehicles. For example, an EV may appear relatively cleaner than a gasoline vehicle when looking at the operation stage. However, it requires electricity that may have been produced at a coal plant, and its batteries may have unique environmental impacts that a gasoline vehicle would not.

Production

The first step in a vehicle's life cycle is its manufacture. Materials such as steel, aluminum and plastics must first be produced and then delivered to vehicle production plants. Here, automotive manufacturers assemble the components into vehicles which are then shipped to dealerships around the world. All of these steps require energy and materials, which will have some impact on the local, regional and global environment. The main differences between the production stage of an EV compared to a conventional vehicle are in the materials used to build EV batteries and the lighter materials often used to build EV frames.

Operation

To fuel a gasoline or diesel vehicle, oil must first be produced from an oil field, transported by pipeline or sometimes truck or rail to a refinery and then distributed to gas stations. The fuel is then combusted in the vehicle. An EV requires fuel just like a gasoline vehicle but, instead of gasoline, its fuel is electricity. A plug-in hybrid requires some electricity and some gasoline, and a hybrid electric vehicle, such as a classic Toyota Prius, only requires gasoline. Typically oil production and transportation as well as electricity production and transmission are non-local activities.

Disposal

At the end of its life a vehicle is sent to a scrap yard where its components are recycled to the fullest extent possible. Since there are very few EVs on the road, it is uncertain how their batteries will be processed at the end of their life. Batteries that are not properly stored could lead to significant environmental impacts, so a proper battery recycling system would be required to avoid environmental harm. Currently, Toxco's facility in Trail, B.C., is the only facility in North America with the capability to recycle lithium batteries.[41] As mentioned in the smart grid section above, some car companies are exploring a way to help offset battery costs and materials by creating a second life for batteries after they leave cars to serve as renewable power storage. Please note that vehicle disposal is not included in this assessment due to limited data. However, any jurisdiction considering mass adoption of EVs should develop a plan for recycling or repurposing used batteries.

This report also does not consider the broader impacts of vehicle dependency, such as urban sprawl and highway development and the increasing distance the average North American drives. These are important considerations and should be addressed in a broader transportation policy, but are outside the scope of this assessment.

How do the life-cycle activities impact the environment?

All of the activities in the production, operation and disposal of a vehicle have some impact on the environment. These impacts can take the form of greenhouse gas emissions, air quality, water use and water quality and impacts on biodiversity and habitat destruction.[42] This analysis focuses on greenhouse gas emissions and air quality for a number of reasons. First, personal transportation accounts for a significant share (14%) of greenhouse gas emissions in the province. Understanding the potential for EVs to reduce transportation emissions is therefore an important part of a greenhouse gas emission reduction strategy. In addition, vehicle air emissions are the largest single source of air

Carbon Monoxide: CO can reduce the ability of the blood to carry oxygen to the heart, brain and other tissues, resulting in impaired performance, respiratory failure and death.

Nitrogen Oxides: NO_x can irriate the lungs and lower resistance to respiratory infections. Under certain weather conditions, NOx can also react with other chemicals to form ground-level ozone, acid rain and secondary particulate matter.

Particulate Matter: $PM_{2.5}$ can be breathed deep into the lungs and contain substances that are particularly harmful to human health. Scientific studies have linked these small particles to premature death, aggravated asthma, acute respiratory symptoms and chronic bronchitis. The particles also scatter light and reduce visibility.

Sulphur Oxides: SO_x can cause health effects such as breathing difficulties, aggravation of existing respiratory and cardiovascular disease and mortality. SO_x can also interact with other compounds in the air to form secondary particulate matter and can lead to acid rain.

Volatile Organic Compounds: Some VOCs can have a potential carcinogenic or toxic effect and can also react with NO_x in the atmosphere to form ground-level ozone, a key constituent of smog.[1]

contaminants in the lower Fraser valley.[43] Air emissions such as nitrogen oxides, sulphur oxides, carbon monoxide, particulate matter and volatile organic compounds contribute to smog and acid rain and are harmful to human health. EVs would need to reduce these air emissions to be considered environmentally superior to gasoline vehicles.

Water, biodiversity and habitat impacts are also important environmental indicators that should be explored in more detail. There is limited information available on the relative impacts of gasoline versus EVs on water, biodiversity and habitat, which are excluded from this analysis.

Which vehicle is better?

The following results are based on the GHGenius model[44] and were generated using the following guidelines:

1. All vehicles are operated in British Columbia.
2. The vehicles compared are personal transport vehicles including an average conventional gasoline vehicle, a battery EV, a plug-in hybrid electric vehicle with 50 km electric range and a hybrid electric vehicle.
3. The vehicles are compared on life-cycle GHG and air emissions, including NO_x, SO_2, CO, VOC and $PM_{2.5}$.
4. The life-cycle emissions are split into local (tailpipe) and non-local (gasoline and/or electricity production and vehicle manufacture).

Figure 1 displays the greenhouse gas life-cycle results for each of the vehicle technologies.

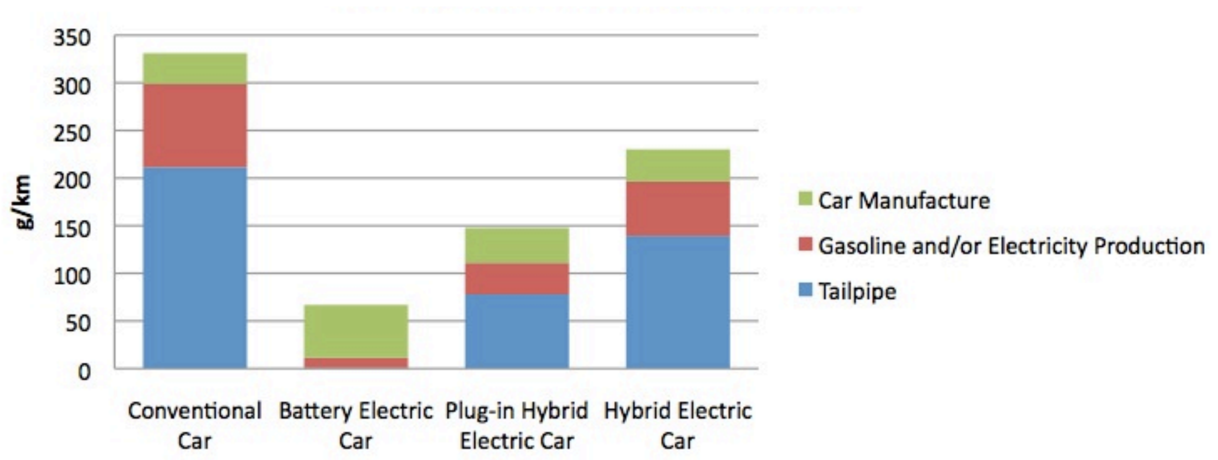

Figure 1. Life cycle GHG emissions for internal combustion, battery electric, plug-in hybrid electric and hybrid electric vehicles

An average gasoline vehicle produces 325 grams of carbon dioxide equivalent for every kilometre it is driven. The majority of these emissions are from the tailpipe of the vehicle (the blue section) and the rest from producing the fuel (red section) and producing the vehicle (green section). Battery electric, plug-in hybrid electric and gasoline hybrids reduce emissions by 80%, 55% and 30% respectively relative to an average gasoline vehicle. The main reason for this better performance is that B.C.'s electricity grid is primarily hydroelectric. EVs are able to use low-carbon electricity in place of gasoline. Hybrid gasoline vehicles do not use the grid and achieve reductions because of increased fuel efficiency relative to gasoline vehicles.

It is worth noting that EV vehicle and battery production (green section) is more energy intensive than a gasoline vehicle; however, reduced GHG emissions during its operation far outweigh the additional energy required to produce the vehicles.

We also looked at the amount of tailpipe air pollutants, such as carbon monoxide, voltatile organic compounds and particulate matter, emitted from each type of vehicle and found EVs emitted less of five key dangerous air pollutants than conventional cars. Figure 2 displays the air emission results for each vehicle. These results are not divided into vehicle manufacture, fuel production and tailpipe emissions; however all of these stages are included. Detailed graphs are provided in the final section of this backgrounder.

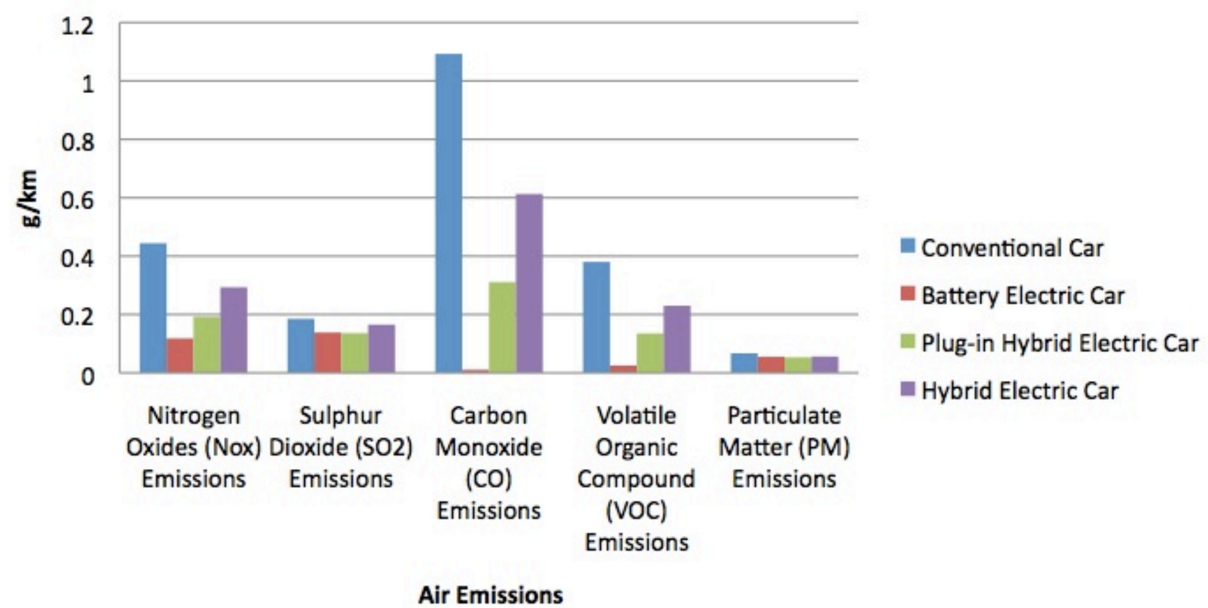

Figure 2. Life cycle air emissions for internal combustion, battery electric, plug-in hybrid electric and hybrid electric vehicles. * CO emissions are presented as g/km x 10^{-1} for ease of viewing on this graph.

For all air emissions, battery electric, plug-in hybrid electric and hybrid electric vehicles outperform combustion vehicles. These reductions are significant and can range from 10% reductions in SO_2 emissions for plug-in hybrid EVs to 99% reductions in CO emissions for battery EVs. Equally important is the location of the air emission reductions. In most cases all three of the alternative vehicle technologies lead to reduced tailpipe, or local air pollutants that generate smog, acid rain and respiratory ailments. They also do not lead to significant increases in air emissions elsewhere in the life-cycle of the vehicle. The main reason for this result is B.C.'s electricity is primarily generated from hydro-electric facilities. Hybrid electrics lead to reduced emissions because they are more fuel efficient than conventional vehicles.

Conclusion

In B.C., EVs are a clear solution to climate change and air quality concerns. This is largely due to the fact that B.C.'s electricity is generated from largely (93%) renewable resources. Electricity generation from renewable sources does have other environmental impacts. Energy conservation can reduce the amount of electricity needed and good planning can minimize the impacts of any new projects.[45]

The primary conclusions of this analysis are summarized below:

- Battery electric, plug-in hybrid electric and hybrid electric vehicles reduce life-cycle greenhouse gas emissions by 80%, 55% and 30% respectively in comparison with gasoline vehicles.
- Battery electric, plug-in hybrid electric and hybrid electric vehicles reduce life-cycle air emissions of NO_x, SO_2, VOCs, PM and CO. The reductions range from 10% to 99% depending on the pollutant and the vehicle.
- Battery electric, plug-in hybrid electric and hybrid electric vehicles could be effective tools to reduce smog and respiratory ailments in urban centres because they primarily reduce local air emissions relative to gasoline vehicles.
- Manufacturing battery electric, plug-in hybrid electric and hybrid electric vehicles produces more GHG emissions and air emissions than a gasoline vehicle; however, this increase in emissions is outweighed by the reductions achieved during the operation of the vehicle.
- B.C.'s electricity grid, which is primarily hydroelectric, is the main reason the battery electric, and plug-in hybrid EVs outperform gasoline vehicles. In a more fossil fuel intensive grid, such as Alberta's, the benefits of battery electric and plug-in hybrid EVs is undermined by a reliance on coal for electricity production. For example, driving a battery electric in Alberta results in just about 4 g/km CO_{2e} savings[46] or 1.1%, while driving a classic hybrid electric in Alberta achieves 104 g/km CO_{2e} savings, or 30% over a conventional vehicle.
- Hybrid electric vehicles outperform conventional vehicles because of their increased fuel efficiency.

Detailed Life-Cycle Analysis Graphs

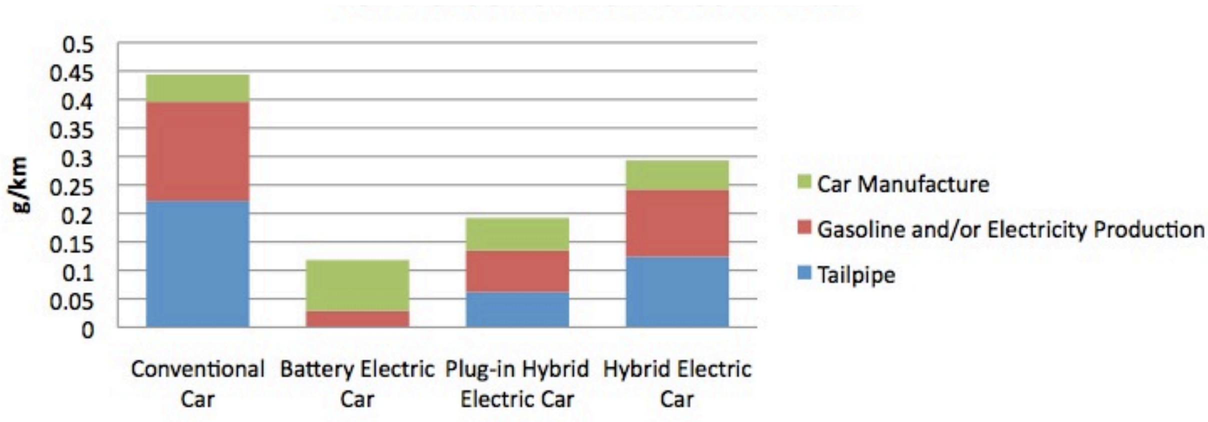

Figure 3. Nitrogen oxides (NOx) emissions for personal vehicles in B.C. — life cycle

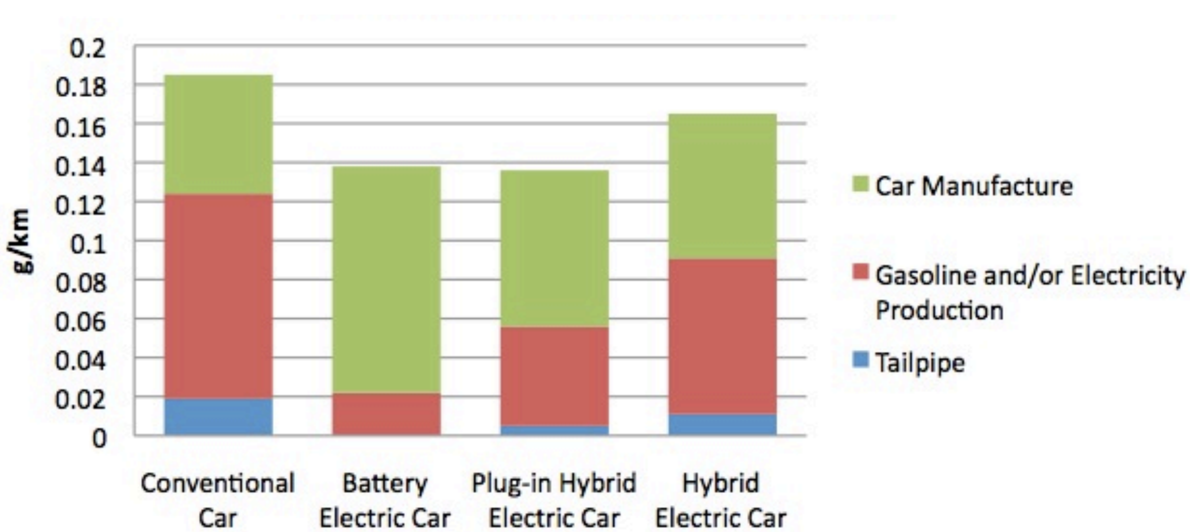

Figure 4. Sulphur dioxide (SO_2) emissions for personal vehicles in B.C. — life cycle

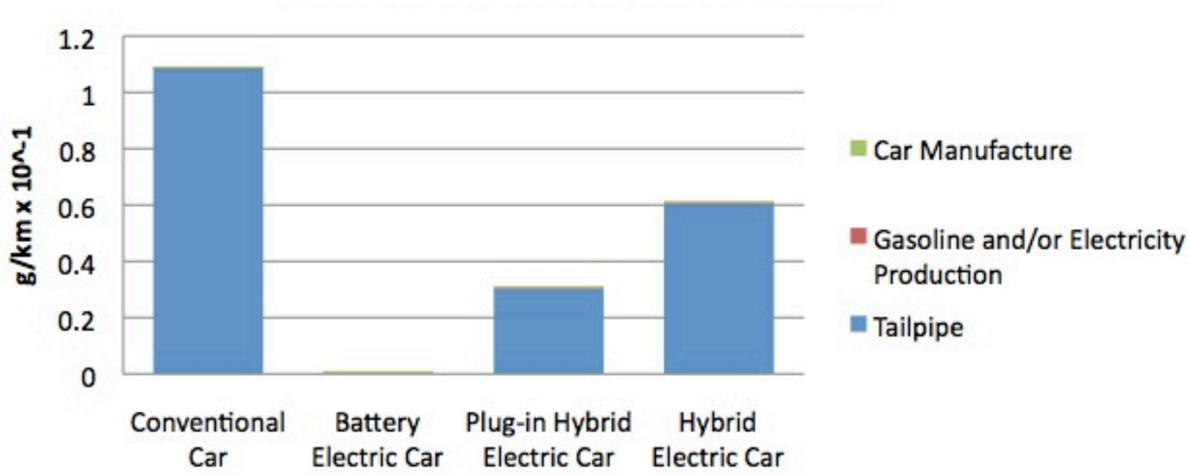

Figure 5. Carbon monoxide (CO) emissions for personal vehicles in B.C. — life cycle

* CO emissions are presented as g/km x 10^{-1} for ease of viewing on this graph.

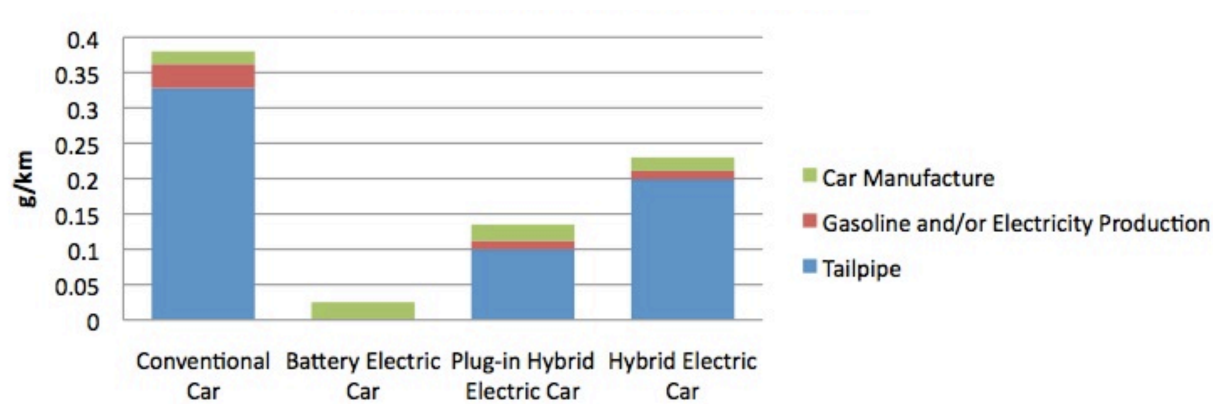

Figure 6. Volatile organic compound (VOC) emissions for personal vehicles in B.C. — life cycle

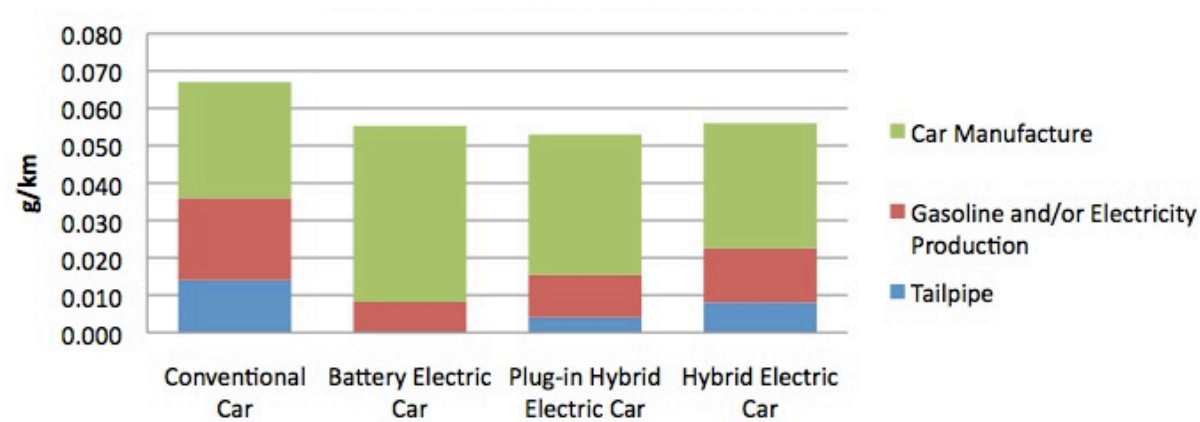

Figure 7. Particulate matter (PM) emissions for personal vehicles in B.C. — life cycle

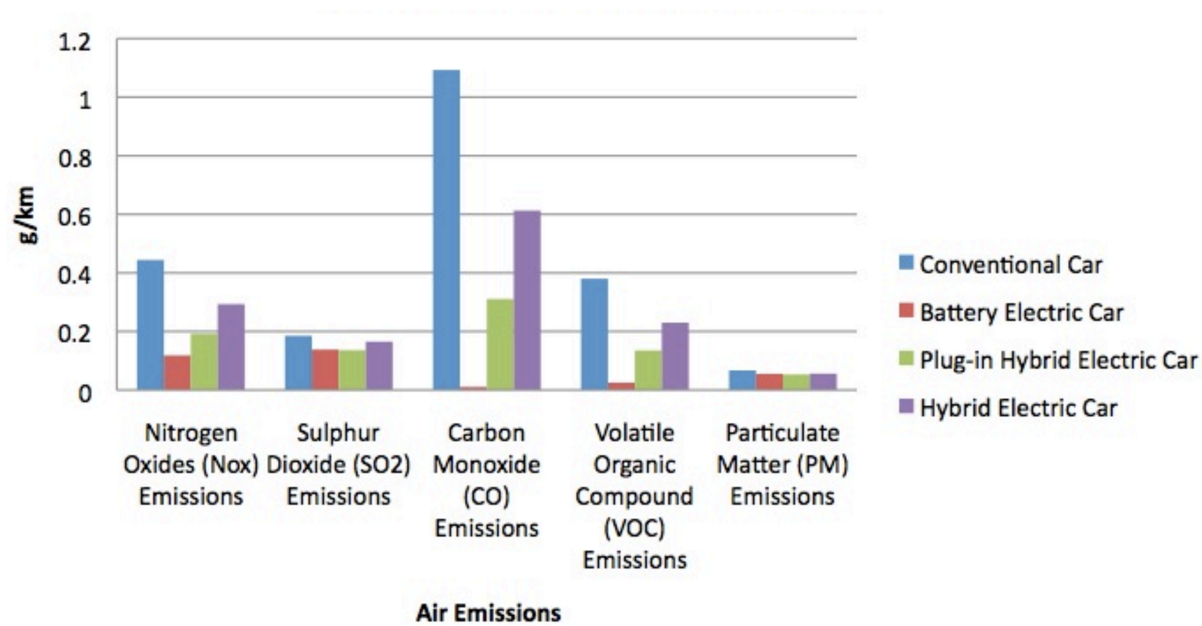

Figure 8. Air quality indicators for personal vehicles in B.C. — life cycle

* CO emissions are presented as g/km x 10^{-1} for ease of viewing on this graph.

Table 2. Life Cycle Emissions for Personal Vehicles in B.C.

Greenhouse Gas (GHG) CO_2eq Emissions	Value (g/km)	Reduction from conventional car
Conventional Car		
Tailpipe	211.4	--
Gasoline and/or Electricity Production	87.6	--
Car Manufacture	32.1	--
Total	**331.1**	**--**
Battery Electric Car		
Tailpipe	0.7	99.7%
Gasoline and/or Electricity Production	10.7	88%
Car Manufacture	55.4	-73%
Total	**66.8**	**80%**
Plug-in Hybrid Electric Car		
Tailpipe	77.9	63%
Gasoline and/or Electricity Production	33.1	62%
Car Manufacture	36.7	-14%
Total	**147.7**	**55%**
Hybrid Electric Car		
Tailpipe	139.4	34%
Gasoline and/or Electricity Production	57	35%
Car Manufacture	33.8	-5%
Total	**230.2**	**30%**

Nitrogen Oxide (NOx) Emissions	Value (g/km)	Reduction from conventional car
Conventional Car		
Tailpipe	0.222	--
Gasoline and/or Electricity Production	0.174	--
Car Manufacture	0.048	--
Total	**0.444**	**--**
Battery Electric Car		
Tailpipe	0	100%
Gasoline and/or Electricity Production	0.029	83%
Car Manufacture	0.089	-85%
Total	**0.118**	**73%**

Plug-in Hybrid Electric Car		
Tailpipe	0.062	72%
Gasoline and/or Electricity Production	0.073	58%
Car Manufacture	0.057	-19%
Total	**0.192**	**57%**
Hybrid Electric Car		
Tailpipe	0.124	44%
Gasoline and/or Electricity Production	0.118	32%
Car Manufacture	0.051	-6%
Total	**0.293**	**34%**

Sulphur Dioxide (SO_2) Emissions	Value (g/km)	Reduction from conventional car
Conventional Car		
Tailpipe	0.019	--
Gasoline and/or Electricity Production	0.105	--
Car Manufacture	0.061	--
Total	**0.185**	**--**
Battery Electric Car		
Tailpipe	0	100%
Gasoline and/or Electricity Production	0.022	79%
Car Manufacture	0.116	-90%
Total	**0.138**	**25%**
Plug-in Hybrid Electric Car		
Tailpipe	0.005	74%
Gasoline and/or Electricity Production	0.051	51%
Car Manufacture	0.08	-31%
Total	**0.136**	**26%**
Hybrid Electric Car		
Tailpipe	0.011	42%
Gasoline and/or Electricity Production	0.08	24%
Car Manufacture	0.074	-21%
Total	**0.165**	**11%**

Carbon Monoxide (CO) Emissions	Value (g/km)	Reduction from conventional car
Conventional Car		
Tailpipe	1.0862	--
Gasoline and/or Electricity Production	0.0047	--
Car Manufacture	0.0017	--
Total	**1.0926**	**--**
Battery Electric Car		
Tailpipe	0	100%
Gasoline and/or Electricity Production	0.0063	-34%
Car Manufacture	0.0041	-141%
Total	**0.0104**	**99%**
Plug-in Hybrid Electric Car		
Tailpipe	0.3038	72%
Gasoline and/or Electricity Production	0.0048	-2%
Car Manufacture	0.0021	-24%
Total	**0.3107**	**72%**
Hybrid Electric Car		
Tailpipe	0.6077	44%
Gasoline and/or Electricity Production	0.0032	32%
Car Manufacture	0.0018	-6%
Total	**0.6127**	**44%**

Volatile Organic Compound (VOC) Emissions	Value (g/km)	Reduction from conventional car
Conventional Car		
Tailpipe	**0.328**	--
Gasoline and/or Electricity Production	0.034	--
Car Manufacture	0.018	--
Total	**0.38**	**--**
Battery Electric Car		
Tailpipe	0	100%
Gasoline and/or Electricity Production	0.001	97%
Car Manufacture	0.024	-33%
Total	**0.025**	**93%**

Plug-in Hybrid Electric Car		
Tailpipe	0.1	70%
Gasoline and/or Electricity Production	0.012	65%
Car Manufacture	0.023	-28%
Total	**0.135**	**64%**
Hybrid Electric Car		
Tailpipe	0.199	39%
Gasoline and/or Electricity Production	0.012	65%
Car Manufacture	0.019	-6%
Total	**0.23**	**39%**

Particulate Matter (PM) Emissions	Value (g/km)	Reduction from conventional car
Conventional Car		
Tailpipe	0.014	--
Gasoline and/or Electricity Production	0.022	--
Car Manufacture	0.031	--
Total	**0.067**	**--**
Battery Electric Car		
Tailpipe	0.000	100%
Gasoline and/or Electricity Production	0.008	63%
Car Manufacture	0.047	-52%
Total	**0.055**	**17%**
Plug-in Hybrid Electric Car		
Tailpipe	0.004	71%
Gasoline and/or Electricity Production	0.011	48%
Car Manufacture	0.038	-21%
Total	**0.053**	**21%**
Hybrid Electric Car		
Tailpipe	0.008	43%
Gasoline and/or Electricity Production	0.015	34%
Car Manufacture	0.033	-8%
Total	**0.056**	**16%**

Endnotes

[1] This estimate includes battery electric and plug-in hybrid electric vehicles. See EMC 2009 Conference Proceedings, Alec Tsang, BC Hydro "*Identifying PEV Early Adopters and their Needs*", available http://www.emc-mec.ca/phev/en/Proceedings.html.

[2] Calculation assumes 1.15 million EVs on the road today (half BEV with 100% fuel displacement, half PHEV with 95% fuel displacement) replacing average conventional cars with 10.2L/100km efficiency, driving an average 16,700 km per year. Also used gasoline GHG emission factor of 2479 g CO_2e / L gasoline. For information on BC's GHG emissions, see http://www.livesmartbc.ca/learn/emissions.html. For information on fuel displacement, see Argonne National Laboratory. (2010). Well-to-Wheels Analysis of Energy Use and Greenhouse Gas Emissions of Plug-In Hybrid Electric Vehicles. Retrieved from http://www.transportation.anl.gov/pdfs/TA/629.PDF.

[3] See http://www.livesmartbc.ca/learn/emissions.html

[4] See http://www.gov.bc.ca/fortherecord/energy/ee_environment.html?src=/environment/ee_environment.html

[5] See http://www.fin.gov.bc.ca/tbs/tp/climate/A4.htm

[6] See EMC 2009 Conference Proceedings, Alec Tsang, BC Hydro "*Identifying PEV Early Adopters and their Needs*", available http://www.emc-mec.ca/phev/en/Proceedings.html.

[7] IBID

[8] See http://vancouver.ca/sustainability/EVcharging.htm

[9] For information on the plug-in electric vehicle working group, contact BC Hydro 1-800-BCHYDRO.

[10] See http://vancouver.ca/sustainability/electric_vehicles.htm

[11] See http://projectgetready.com/

[12] Statistics Canada (2006) Commuting Patterns and Places of Work of Canadians, 2006 Census http://www12.statcan.ca/census-recensement/2006/as-sa/97-561/p35-eng.cfm

[13] See http://www.plugincars.com/

[14] For more information on US investments in electric vehicles through the Recovery Act and the Advanced Technology Vehicles Manufacturing loan program, see http://www.energy.gov/news/9212.htm

[15] See http://www.bchydro.com/about/our_commitment/sustainability/plugin_vehicles.html

[16] Editorial. 2010. Vancouver Firms Partnering to Deploy Electric Vehicles and Charging Stations. *Business in Vancouver*, Aug 4, Business Today http://www.bivinteractive.com/index.php?option=com_content&task=view&id=2875&Itemid=32 (Accessed August 5, 2010)

[17] See http://www.coulombtech.com/

[18] See http://www.portlandgeneral.com/our_company/news_issues/news/08_05_2010_pge_opens_north_america_s_fir.aspx

[19] Electric Mobility Canada. *Electric Vehicle Transportation in Canada, Media Backgrounder* (Mississauga: EMC, 2010), 2.

[20] Simpson, A. *Cost-Benefit Analysis of Plug-in Hybrid Electric Vehicle Technology* (Yokohama, Japan: National Renewable Energy Laboratory, 2006), 11.

[21] Assuming an average annual driving distance in B.C. of 16,700 km, and EV efficiency of 0.2 kWh/km and an ICE efficiency of 8 litres/100 km; does not incorporate the reduced cold weather efficiency of EVs. For more information, see EMC 2009 Conference Proceedings, Alec Tsang, BC Hydro "*Identifying PEV Early Adopters and their Needs*", available http://www.emc-mec.ca/phev/en/Proceedings.html.

[22] To use the PGR calculator, see http://projectgetready.com/js/tco.html

[23] See http://www.azuredynamics.com/products/transit-connect-electric.htm

[24] See http://www.rapidelectricvehicles.com/300acx.html

[25] To use REV's ROI calculator, see http://www.rapidelectricvehicles.com/roi-calculator.html

[26] TAF's EV300 initiative aims to get at least 300 electric vehicles on the road in the Greater Toronto Area by 2012, see http://www.fleetwise.ca/ev300.php

[27] See http://www.greenfleetsbc.com/

[28] Tomic J., and Kempton, W., 2007. Using fleets of electric drive vehicles for grid support. Journal of Power Sources 168 (2007) 459–468.

[29] Kelly et al. *Electrifying the BC Vehicle Fleet: Opportunities and Challenges for Plug-in Hybrid, Extended Range & Pure Electric Vehicles* (Victoria, BC: Pacific Institute for Climate Solutions, 2009), 17.

[30] Assuming 0.2 kWh/km this would cover 65 kilometres of EV use per day.

[31] Kelly et al., 9.

[32] Assumptions used in calculation: 2.7 million licensed vehicles in B.C., average passenger vehicle use is 17,000 km/year, and EPVs use 0.2 kWh/km. Source: 2008 BC Hydro Long-Term Acquisition Plan Application.

[33] Visit the consumer website, here http://www.vancouver.ca/ev

[34] Editorial. 2010. No, Electric Vehicles Won't Bring Down the US Power Grid. *Discovery News*, July 12, Tech News http://news.discovery.com/tech/electric-vehicles-wont-bring-down-power-grid.html (Accessed July 26, 2010)

[35] See EMC 2009 Conference Proceedings, Alec Tsang, BC Hydro "*Identifying PEV Early Adopters and their Needs*", available http://www.emc-mec.ca/phev/en/Proceedings.html.

[36] Editorial. 2010. Who Buys a 2011 Nissan Leaf? Toyota Prius Owners Of Course. GreenCarReports.com, June 2, Blog http://www.greencarreports.com/blog/1045740_who-buys-a-2011-nissan-leaf-toyota-prius-owners-of-course

[37] EMC 2009 Conference Proceedings, Alec Tsang, BC Hydro "*Identifying PEV Early Adopters and their Needs*", available http://www.emc-mec.ca/phev/en/Proceedings.html.

[38] Editorial. 2010. No, Electric Vehicles Won't Bring Down the US Power Grid. *Discovery News*, July 12, Tech News http://news.discovery.com/tech/electric-vehicles-wont-bring-down-power-grid.html (Accessed July 26, 2010)

[39] Kelly et al., 2.

[40] For a list of assumptions used in this estimate, see endnote 240.

[41] See http://www.toxco.com/press_release.html

[42] Bipartisan Policy Center. (2009). Performance Driven: A New Vision for U.S. Transportation Policy. Retrieved from http://www.bipartisanpolicy.org/sites/default/files/NTPP Report.pdf.

[43] Metro Vancouver. (2010). Air Emissions & Emission Reduction Programs. Retrieved from http://www.metrovancouver.org/services/air/emissions/Pages/default.aspx.

[44] All results from GHGenius 3.18 for B.C. with electricity for electric and plug-in hybrid electric vehicles from the B.C. grid, see http://www.ghgenius.ca/

[45] For more information on Pembina's recommendations from December 2009 on how clean electricity projects are planned and permitted in B.C., see http://www.pembina.org/pub/1951

[46] Results from GHGenius 3.18 for Alberta with electricity for battery electric vehicles from Alberta grid: a conventional vehicle - 341 g/km; a battery electric vehicle - 337.3 g/km; a hybrid electric vehicle - 237 g/km. For more information about GHGenius, see http://www.ghgenius.ca/