

# Electric vehicles in Nova Scotia: An examination of availability, affordability, and acceptability issues

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## **Abstract**

In December 2015, the Canadian government made a commitment to achieving the goals specified in the Paris Agreement at COP-21. The most significant of these commitments being an agreement to reduce Canada's annual greenhouse gas emissions to a level that will hold the global average temperature to well below 2°C and to pursue efforts to limit the temperature increase to 1.5°C. Past greenhouse gas emissions reduction efforts by all levels of government in Canada have focused primarily on power generation (to reduce emissions) and the built environment (to reduce energy demand). Canada's commitment to the Paris Agreement means that these efforts must be redoubled and similar efforts will need to be applied to the transportation sector, given the emissions associated with this sector.

Road transportation emissions are of particular importance in a province such as Nova Scotia where they are responsible for over 19% of total provincial emissions. A barrier to reducing emissions from conventional road vehicles has been the availability of both alternative fuels and the vehicles to use these fuels. However, over the past decade, considerable progress has been made, especially with electric vehicles, which, if powered by renewable sources of electricity, can result in a reduction in transportation-related emissions.

This report examines some of the risks associated with the adoption of electric vehicles in the province of Nova Scotia through the lens of three energy security indicators: acceptability, availability, and affordability. It shows that as Nova Scotia Power reduces its greenhouse gas emissions, the environmental acceptability of electric vehicles will increase. While the availability of electricity is not an issue, the need for increased charging may be a problem during cold-weather driving and, should electric vehicles become popular, Nova Scotia Power will need to address the issue of uncoordinated electricity charging by upgrading its grid and implementing a smart grid.

The report also considers some of the affordability issues associated with electric vehicles in Nova Scotia. While the per-kilometre cost of driving an electric vehicle is less than that of a conventional vehicle (in part because of the various road and fuel taxes that electric vehicle owners do not pay), both the base-cost and annualized-cost of electric vehicles are greater than those associated with many conventional vehicles sold in the province.

Other topics discussed include public perceptions of electric vehicles, the direct and indirect subsidization of electric vehicles, and possible alternatives to light-duty passenger electric-vehicles.

## Glossary

BEV	Battery Electric Vehicle
CV	Conventional Vehicle
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
g	gram
Gt	Gigatonne ( $1 \times 10^9$ tonnes)
GtCO <sub>2e</sub>	Gigatonnes carbon-dioxide equivalent
h	Hour
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
kg	kilogram (1,000 g)
km	kilometre
kWh	kilowatt-hour
L	Litre
Mt	Megatonne ( $1 \times 10^6$ tonnes)
NRCan	Natural Resources Canada
NSP	Nova Scotia Power
PHEV	Plug-in Hybrid Electric Vehicle
PM <sub>2.5</sub>	Particulate Matter 2.5 micron
PM <sub>10</sub>	Particulate Matter 10 micron
t	tonne (1,000 kg)

## Acknowledgements

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# Electric vehicles in Nova Scotia: An examination of availability, affordability, and acceptability issues

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## 1 Introduction

In December 2015, the Canadian government made a commitment to achieving the goals specified in the Paris Agreement at COP-21, the most significant being an agreement to reduce global annual greenhouse gas emissions to a level that will hold the global average temperature to well below 2°C and to pursue efforts to limit the temperature increase to 1.5°C (UNFCCC, 2015, p. 21 (Article 2.1 (a))). Meeting the 2°C target requires a significant decline in annual global greenhouse emissions, from an estimated 52.7±5 GtCO<sub>2e</sub> in 2014 to 48 GtCO<sub>2e</sub> (a decline of about 9%) in 2025 and 42 GtCO<sub>2e</sub> in 2030 (a decline of about 20% from 2014) (UNEP, 2015).

Attempts at emissions reduction by both the federal and provincial governments since 1990 have produced a variety of results. As Table 1 shows, Canada’s total national emissions grew by over 18% between 1990 and 2013, whereas Nova Scotia’s emissions fell by 9.4%.<sup>1</sup> Programs and regulations targeting emissions from electrical generation fell nationally by almost 7.5%, but increased by 5.5% in Nova Scotia,<sup>2</sup> whereas emissions reduction programs in the built environment (residential and commercial-institutional) remained unchanged nationally, but fell by almost a quarter in Nova Scotia. Despite the economic slowdown starting in 2008, all provinces (with the exception of the three territories) experienced a growth in emissions from road transportation; for example, over 40% nationally and almost 13% in Nova Scotia.

**Table 1: Changes in emissions between 1990 and 2013 for Canada and Nova Scotia (Mt)  
(Canada, 2015a)**

Emissions source:	Canada			Nova Scotia		
	1990	2013	Change	1990	2013	Change
Total	613.0	726.0	18.4%	20.2	18.3	-9.4%
Electricity generation	94.5	87.5	-7.4%	6.9	7.3	5.5%
Built environment	74.7	74.7	0.0%	3.2	2.4	-24.1%
Road transportation	97.7	137.0	40.2%	3.1	3.5	12.8%

If the federal, provincial, and municipal governments are to make any headway in meeting Canada’s Paris Agreement commitments, not only will existing programs targeting electrical

<sup>1</sup> Nova Scotia’s 9.4% decline in emissions since 1990 is due in large part to a reduction of almost 79% in fugitive emissions from the closure of coal mines between the mid-1990s and early 2000s.

<sup>2</sup> Although Nova Scotia’s 2013 greenhouse gas emissions from electricity are higher than they were in 1990, they are now declining from a peak in 2005, both in terms of total and per-kWh emissions. This is attributable to a decline in industrial demand, an increased use of natural gas and variable-renewables, and a significant uptake of heat pumps in the residential sector.

generation and the built-environment need to be redoubled, it will also be necessary to make reductions in the road transportation sector as well.

The ability to transport both people and goods is essential to the economic wellbeing of any jurisdiction (World Bank, 2015). Many of the significant economic and social changes that have taken place over the last 120 years are due, at least in part, to the evolution of local, national, and global transportation systems (Wolf, 1996). An essential component of these improvements has been the availability of supplies of crude oil that can be refined into transportation fuels such as gasoline/petrol, diesel, aviation fuel, and marine bunkers (IEA, 2014).

However, the past quarter century has seen growing concerns over the social and environmental impacts of crude oil extraction, refining, and transportation, the volatility of crude oil prices, and emissions (including various greenhouse gases, nitrogen oxides, and particulate matter, notably PM10 and PM2.5) associated with the combustion of refined petroleum products. In response, a number of jurisdictions have called for the introduction of cleaner vehicles and have given incentives to both manufacturers and consumers. These alternative-fuel vehicles rely on a variety of fuels (including ethanol, gasoline, natural gas, propane, and electricity) and conversion technologies (typically internal combustion engines or electric motors, or both).

Of the different types of alternative-fuel vehicles on the market, one that is of interest to many electricity suppliers and promoters of these vehicles is the battery-electric vehicle or BEV. Given the right electricity-supplier fuel-mix and climate conditions, a BEV can have both fewer emissions and lower fuel-costs than a comparable conventional vehicle with an internal combustion engine (ICE) operating on a liquid fuel such as a gasoline or diesel.

This report examines some of the issues facing a jurisdiction if its existing conventional and hybrid-electric light-duty vehicles are replaced by battery-electric light-duty vehicles. The risks are discussed in terms of three energy-security indicators (Hughes, 2012; Hughes & Ranjan, 2013):

**Availability:** The availability of both the vehicle and the energy needed by the vehicle to allow the driver and any passengers to reach their intended destination in a timely manner.

**Affordability:** The cost of the energy used by the vehicle, the lifetime cost of owning and operating the vehicle, as well as a variety of societal costs.

**Acceptability:** The greenhouse-gas emissions associated with the vehicle.

The indicators are applied to Nova Scotia, where the electricity supplier, Nova Scotia Power, is in the process of reducing its greenhouse gas emissions from over 900 kg of CO<sub>2</sub>e/MWh in 2005 to a projected 400 kg of CO<sub>2</sub>e/MWh by 2035. The report shows that while battery-electric vehicles will be more environmentally acceptable in the province, there may be availability and affordability issues that limit their adoption. Despite these possible shortcomings, the report briefly examines other battery-electric passenger-vehicle options that offer the province a way to take advantage of electric transportation.

## 2 Background

### 2.1 Vehicle categories and terminology

This report considers four categories of light-duty vehicle, classified by the type of fuel they use (gasoline or electricity, or both) and how the fuel is transformed into rotary motion (gasoline engine or electric motor, or both).

Vehicles that rely on a liquid fuel (typically gasoline or petrol) fall into one of two categories:

**CV:** Conventional vehicles that use an engine to convert the liquid fuel into kinetic energy for its motive power.

**HEV:** A hybrid-electric vehicle derives its motive power from an electric motor with electricity supplied by an on-board gasoline or diesel generator. Energy is stored in both batteries and a fuel tank.

Plug-in electric vehicles (or PEVs) are, as the name suggests, vehicles that derive some or all of their motive power from an external source of electricity. Broadly speaking, these fall into one of (PlugInCars, 2015):

**BEV:** A battery electric vehicle is one which derives all of its motive power from mains electricity, with the energy stored in batteries.

**PHEV:** A plug-in hybrid-electric vehicle derives a portion of its motive power from mains electricity, the remainder comes from an on-board gasoline or diesel generator. Energy is stored in both batteries and a fuel tank.

### 2.2 Five-cycle testing

The energy intensity (energy consumed per kilometre) and range data for the four different vehicle categories examined in this report are taken from NRCan's 2015 Fuel Consumption Guide (NRCan, 2015a). The data in the 2015 Fuel Consumption Guide is obtained from a five-cycle testing method that more closely represents typical driving conditions than the earlier three-cycle method (NRCan, 2015b). These tests are applied to all vehicles listed in its Fuel Consumption Guide and are shown in Table 2.

**Table 2: NRCan’s five cycle tests and associated test parameters (from (NRCan, 2015b))**

Test parameters	Cycle test				
	City	Highway	Cold	Air Conditioning	High speed and quick acceleration
Test Cell Temperature	20°-30°C	20°-30°C	-7°C	35°C	20°-30°C
Total time (minutes seconds)	31' 14"	12' 45"	31' 14"	9' 56"	9' 56"
Distance (km)	17.8 km	16.5 km	17.8 km	5.8 km	12.9 km
Top speed (km/h)	90 km/h	97 km/h	90 km/h	88 km/h	129 km/h
Average speed (km/h)	34 km/h	78 km/h	34 km/h	35 km/h	78 km/h
Maximum acceleration (km/h per second)	5.3 km/h per second	5.2 km/h per second	5.3 km/h per second	8.2 km/h per second	13.6 km/h per second
Number of stops	23	0	23	5	4
Idling time (% of total time)	18%	0%	18%	19%	7%
Engine start	Cold	Warm	Cold	Warm	Warm

### 2.3 Vehicles considered

Unless otherwise indicated, the report considers only those light-duty passenger vehicles with the best fuel consumption rating in their category (i.e., conventional, hybrid-electric, plug-in hybrid-electric, or electric). There are two reasons for this: first, they represent a baseline for their category’s acceptability and affordability; any other vehicle considered in that category will be less acceptable and less affordable.<sup>3</sup> Second, by limiting the number of vehicles considered, it improves the readability of graphs.

The vehicle ranges, when listed, assume a fully charged battery or a full tank of fuel, while the recharge time is the time required to fully recharge a battery at 240 volts. “Combined driving” refers to an average of 55% city driving and 45% highway driving. NRCan’s vehicle classes are listed in Table 3.

**Table 3: Vehicle classes (NRCan, 2015a)**

Symbol	Class	Interior volume
S	Subcompact	2405-2830 L (85-99 ft <sup>3</sup> )
C	Compact	2830-3115 L (110-119 ft <sup>3</sup> )
M	Mid-size	3115-3400 L (110-119 ft <sup>3</sup> )
L	Full-size	3400 L (120 ft <sup>3</sup> ) or more

All of the data is subject to NRCan’s long-standing disclaimer, “Your fuel consumption will vary”.

#### 2.3.1 Conventional Vehicles

Not surprisingly, there are over 1000 CVs listed in the Fuel Consumption Guide. Of these, the Mitsubishi Mirage offers the best fuel consumption ratings (see Table 4).

<sup>3</sup> With respect to availability, it is assumed that all vehicles in a category are available (that is, they can be purchased in Canada) and that unless otherwise indicated, the necessary supply of gasoline or electricity is available.

**Table 4: Best-in-category CV (NRCAN, 2015a)**

Make-Model	Class	City	Highway	Combined
		L/100km		
Mitsubishi Mirage	C	6.4	5.3	5.9

### 2.3.2 Hybrid Electric Vehicles

NRCAN ranks HEVs and CVs together in the Fuel Consumption Guide as both categories are considered liquid-fueled vehicles. The Toyota Prius is the best liquid-fueled vehicle, regardless of category (i.e., CV or HEV); its fuel consumption ratings are listed in Table 5.

**Table 5: Best-in-category HEV (NRCAN, 2015a)**

Make-Model	Class	City	Highway	Combined
		L/100km		
Toyota Prius	M	4.6	4.9	4.7

### 2.3.3 Plug-in hybrid

The Fuel Consumption Guide lists nine vehicles in its PHEV category. Of these, two stand out because of their different approaches to operating as a plug-in hybrid (see Table 6): the BMW i3 REX (Range-Extender) is the best-in-category in terms of its combined-electric intensity (17.9 kWh/100km) and its electric-only distance (116 km), while the Toyota Prius Plug-in is the best-in-category with respect to its consumption of gasoline (4.7 L/100km), although it has the lowest-in-category electric-only range (17 km). The BMW i3 REX is essentially a BEV with hybrid capabilities added,<sup>4</sup> whereas the Toyota Prius Plug-in operates as a hybrid with plug-in capabilities.

**Table 6: Best-in-category PHEVs (NRCAN, 2015a)**

Make-Model	Class	Motor (kw)	City	Highway	Combined	Combined (Electric)		Elec. km	Fuel km
			L/100 km			kWh/100km	L/100km		
BMW i3 REX	S	125	5.7	6.3	6.0	17.9	0.0	116	119
Toyota Prius Plug-in	M	60	4.7	4.8	4.7	18.0	0.4	17	845

While the 2015 Fuel Consumption Guide PHEV data lists the gasoline consumption for city, highway, and combined driving conditions (L/100km), it gives only the electric intensity for combined driving conditions (kWh/100km).

Unless otherwise indicated, any references to PHEV in the analysis refers to the BMW i3 REX.

### 2.3.4 Battery Electric Vehicles

NRCAN lists 12 battery-electric vehicles in its 2015 Fuel Consumption Guide. Although the most widely known BEVs are probably the Nissan Leaf and various Tesla models, the best-in-category is the sub-compact BMW i3, the battery-electric version of the BMW i3 REX (see Table 7).

<sup>4</sup> Vehicles such as the BMW i3 REX can be classified as REEVs or Range Extended Electric Vehicles (REEV, n.d.).

**Table 7: BEVs (NRCan, 2015a)**

Make-Model	Class	Motor (kW)	City	Highway	Combined	Range (km)	Recharge (h)
			(kWh/100km)				
BMW i3	S	125	15.2	18.8	16.8	130	4
Nissan Leaf	M	80	16.5	20.8	18.4	135	5
Tesla Model S	L	283	23.9	23.2	23.6	426	12

The analysis considers both the BMW i3 and Nissan Leaf.

## **2.4 Nova Scotia – background and motor vehicle information**

### **2.4.1 Background**

Nova Scotia is Canada’s second smallest province with an area of 55,283 km<sup>2</sup>. It has a population of about 940,000 (Statistics Canada, 2014a); given its ageing population and limited net migration, most population projections expect little or no population growth over the next 20 years (The Daily, 2014).

In 2012, Nova Scotia had the third lowest median family income (\$70,020) of any province or territory in Canada; the national median family income was \$76,550 (Statistics Canada, 2015a).<sup>5</sup>

### **2.4.2 Motor vehicles**

In 2013, there was a total of 615,561 road motor vehicle registrations in Nova Scotia (Statistics Canada, 2015c); of these, over 93% had a curb-weight of less than 4,500 kg and are classified as cars or light trucks (NRCan, 2015a; Statistics Canada, 2015c).<sup>6</sup>

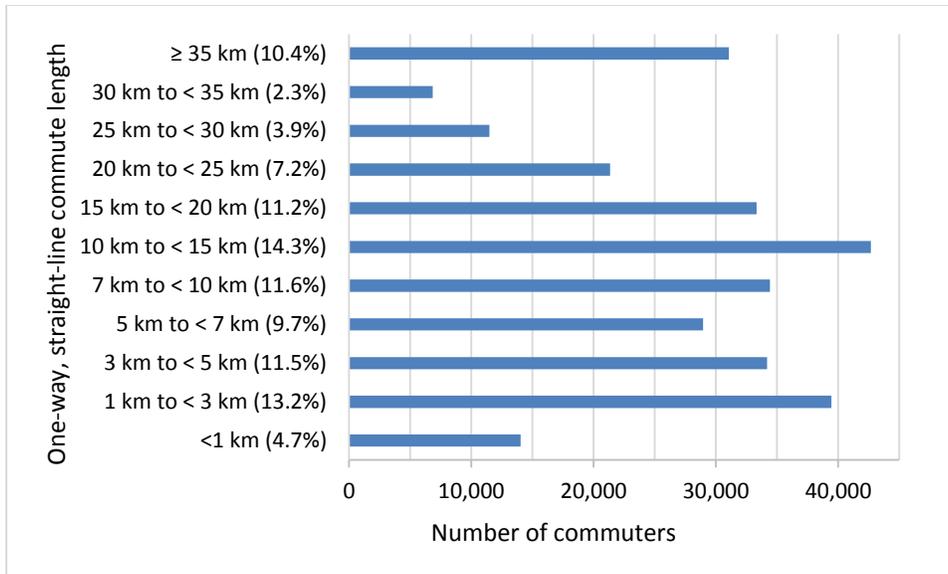
The average distance travelled in 2012 by a vehicle in Nova Scotia was estimated to be 22,100 km (NRCan, 2015d). Motor gasoline met almost 93% of the energy used for passenger road transportation, while diesel and ethanol were responsible for almost 4% and slightly over 3%, respectively (NRCan, 2015c).

In the 2010 census, of the 355,265 Nova Scotians who identified themselves as commuters, 83.8% relied on cars, trucks, or vans (either as the driver or as a passenger), while 15.1% used sustainable transportation (i.e., public transit and active transportation). Of the 297,800 commuting by car, truck, or van, 269,975 were drivers (Statistics Canada, 2013).

The straight-line distance travelled by those relying on a car, truck, or van in Nova Scotia is shown in Figure 1. Over 37% of commuters had a straight-line of between 7 km and 20 km, while almost 17% had a straight-line distance more than 25 km.

<sup>5</sup> Census families include couple families, with or without children, and lone-parent families (Statistics Canada, 2015a).

<sup>6</sup> NRCan defines light trucks as pickup trucks (small - less than 2,722 kg and standard - 2,722-3856 kg), sport utility vehicles (small: less than 2,722 kg and standard: 2,722-4536 kg), minivan (less than 3,856 kg), van (cargo: less than 3,856 kg and passenger: less than 4,536 kg), and special purpose vehicles (less than 3,856 kg) (NRCan, 2015a).

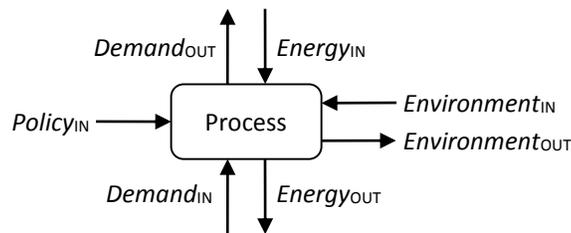


**Figure 1: Number of car, truck, or van commuters in Nova Scotia by straight-line distance**  
**Percentages denote percent of total commuters (Statistics Canada, 2013)**

The typical round-trip distance is assumed to be 30% more than twice the straight-line distance;<sup>7</sup> for example, the estimated round-trip distance for the 10 km to 15 km straight-line distance grouping is in the range of 26 km to 39 km, while almost one-quarter of Nova Scotians had an estimated round-trip commuting distance of at least 52 km (20 km straight-line distance  $\times 2 \times 1.3$ ).

## 2.5 Energy processes and flows

An energy system consists of processes organized into chains from an energy source to an energy service. A process, such as in Figure 2, attempts to meet a request for energy from a downstream process or service (a  $Demand_{IN}$  flow) by processing a flow of energy from an upstream process or energy source (an  $Energy_{IN}$  flow); the process will interact with its environment (the  $Environment_{IN}$  and  $Environment_{OUT}$  flows).



**Figure 2: A process and its energy flows (Hughes, 2012)**

A gasoline engine or electric motor are examples of processes. A  $Demand_{IN}$  flow to an engine or motor is the driver's demand to travel a certain distance, while the  $Energy_{OUT}$  flow is the kinetic energy produced to move the vehicle over the required distance.

<sup>7</sup> The average distance travelled is estimated to be 30% longer than the straight-line distance (Hughes & Sundaram, 2011).

Each  $Energy_{OUT}$  flow is associated with a unit-energy cost such as dollars-per-litre or cents-per-kilowatt-hour. The cost of this flow is determined by the cost of the process and its  $Energy_{IN}$  flows. Each upstream process in the chain contributes to the cost of the  $Energy_{OUT}$  flow.

A gasoline engine consumes gasoline, its  $Energy_{IN}$  flow, to meet  $Demand_{IN}$ , in doing so, also produces heat and greenhouse gases that are released to the environment ( $Environment_{OUT}$ ). Although an electric motor consumes electricity without the emissions associated with a gasoline engine, the electricity itself may have been produced by upstream processes with carbon-intensive fuels such as coal, refined oil, or natural gas. Any emissions or other environmental impacts upstream of the electricity generator or the refinery gate are not considered in this report.

Changes to a process's different flows can affect the energy security of the process or the upstream and downstream processes in its chain (Hughes & Ranjan, 2013). These changes can be discussed in terms of availability, affordability, and acceptability.

### **3 Availability**

Availability is the ability of a process to meet its energy demands. In the case of an electric vehicle, availability involves a process (i.e., an electric motor) converting an  $Energy_{IN}$  flow (electricity stored in a battery) into the  $Energy_{OUT}$  flow (i.e., motive or kinetic energy) required to move the vehicle from the place of origin to the intended destination. If an event occurs that makes the vehicle inoperable or one that limits the  $Energy_{IN}$  flow, making it difficult or impossible to meet the driver's transportation requirements, then an availability event is said to have occurred (Hughes & Ranjan, 2013).

If the vehicle is maintained properly, then the vehicle operator's concern is exhausting the vehicle's battery before the destination can be reached (this applies equally to PHEVs with an empty fuel tank or BEVs). This is referred to as range anxiety. This section presents some examples of causes of range anxiety: temperature and the use of auxiliary services; the availability of infrastructure; and uncoordinated load caused by simultaneous charging.

#### **3.1 Temperature**

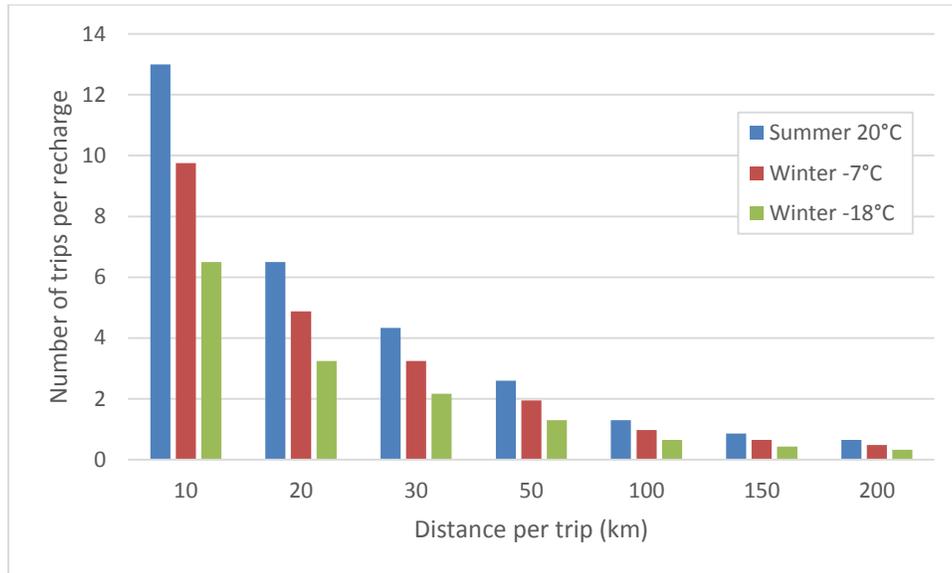
Electric vehicles are sensitive to temperature for at least two reasons.

First, the Li-ion (lithium ion) batteries used in electric vehicles are affected by temperature extremes, making charging more difficult in cold weather and degrading the lithium in high temperatures (Pesaran, Santhanagopalan, & Kim, 2013). This can add to the cost of the vehicle by reducing the battery's expected lifetime and, in some extreme cases, result in battery fires (Pesaran, Santhanagopalan, & Kim, 2013).

Second, the range of a BEV decreases when operating in sub-zero temperatures, in part because of a decline in battery efficiency but also with the use of auxiliary services, notably cabin heating. In vehicle-laboratory tests, Transport Canada found that BEV range was reduced by about 25% at  $-7^{\circ}\text{C}$  if cabin heating was used (compared with operating the vehicle at  $-7^{\circ}\text{C}$  with no heating), while at  $-18^{\circ}\text{C}$ , the use of maximum cabin heating reduced vehicle range by more than 50% compared with operating the vehicle at  $20^{\circ}\text{C}$  with no heating or cooling (Meyer, Whittal,

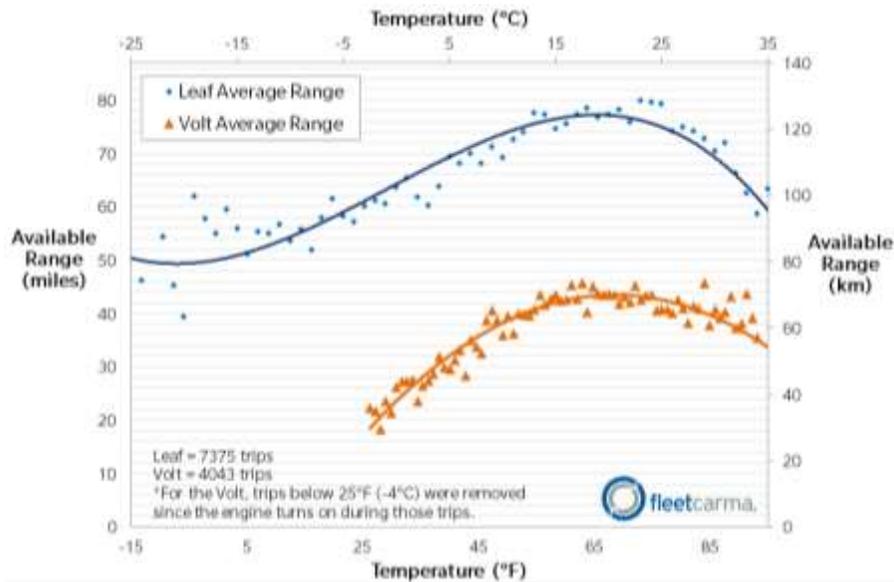
Christenson, & Loiselle-Lapointe, 2012). The cold weather was also found to affect battery capacity, reducing it by 4% at -7°C to about 8% at -18°C (compared to 20°C).

The potential effects of cold weather on a BEV with a 130 km range per full-charge are shown in Figure 3. For example, about two-and-a-half 50-km trips could be made on a single full-charge during the summer months; this would be expected to fall to just under two trips when driving at -7°C and about 1.3 trips at -18°C.



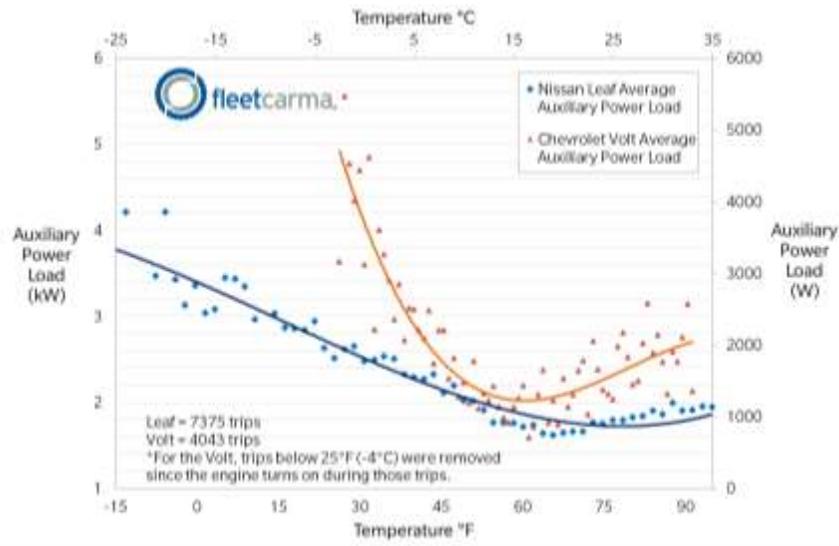
**Figure 3: Expected number of possible trips with a fully charged BEV (summer at 20°C and winter at -7°C and -18°C)**

Vehicle-data collected by FleetCarma from on-board sensors in Nissan Leafs and Chevrolet Volts corroborate the vehicle-laboratory test results (FleetCarma, 2014). In Figure 4, the relationship between temperature and the expected available-range for the Leaf is shown based on over 7,300 trips; the data does not indicate whether the vehicle was using cabin heat, the state of the vehicle, the road conditions, or the distance driven.



**Figure 4: Range vs Temperature for Nissan Leaf (BEV) and Chevrolet Volt (PHEV) (FleetCarma, 2014)**

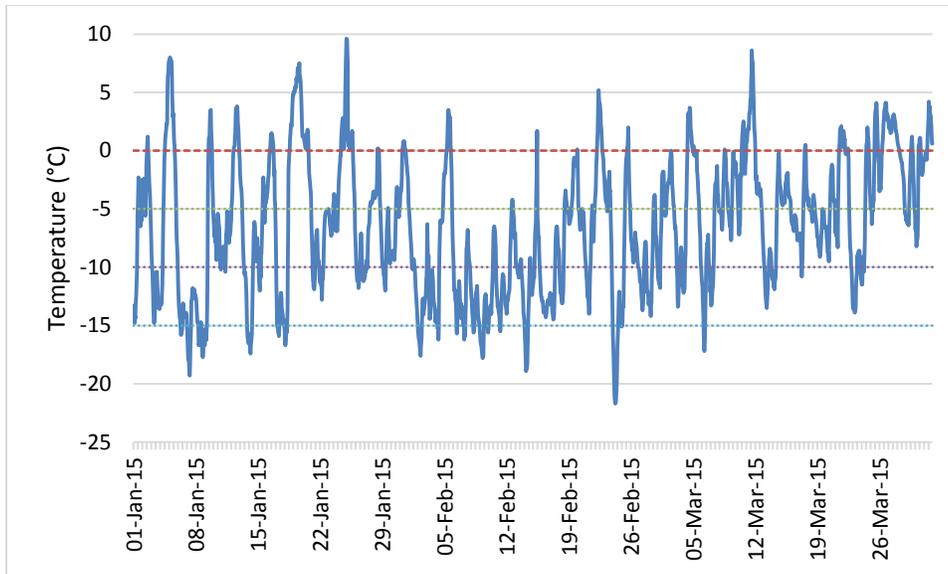
Figure 5 shows how the reliance on cabin heating increases the auxiliary power load as the temperature drops.



**Figure 5: Average Auxiliary Power Load vs. Temperature for Nissan Leaf and Chevrolet Volt (FleetCarma, 2014)**

### 3.1.1 Nova Scotia: Winter driving

Despite being nearly surrounded water, Nova Scotia typically experiences four months of the year (January, February, March, and December), with below-zero temperatures (Canada, 2015b). As an example, Figure 6 shows the hourly temperatures observed at Halifax Stanfield International Airport from 1 January 2015 through 31 March 2015.



**Figure 6: Hourly temperatures for Halifax International Airport (January-to-March 2015) (Canada, 2015c)**

During the months of January through March in Nova Scotia, it is reasonable to expect that extended periods of sub-zero temperatures will both reduce the maximum distance an electric vehicle can travel (as shown in Figure 3) and increase the demand for electricity (Yuksel & Michalek, 2015).

The reduction in possible distance travelled between January and March can be expected to affect all drivers of electric vehicles; however, since BEVs are typically used for commuting (Botsford, 2015), the most significant impact will be on those with sizeable commutes. Table 8 shows the commuting distances between Halifax and a variety of locations (both within Halifax and nearby communities); it is the actual distance, measured from the center of each jurisdiction, and does not include any vehicle activity within the jurisdiction. Each commuting distance is well within the advertised ranges of the BMW i3 and Nissan Leaf of about 130 km for a fully-charged vehicle (see Table 7). At 20°C, all vehicles, if fully charged, would have sufficient charge to travel the different commuting distances. The return trip would require most vehicles to be recharged; commuters from Windsor and Chester might recharge their vehicles despite the distance requiring about half a battery's charge (see Table 8).

**Table 8: One-way commuting distance between Halifax and selected locations  
(Distance Canada, n.d.)<sup>8</sup>**

To/from Halifax	One-way distance (km)	Number of charges required to complete journey		
		20°C 130 km	-7°C 97 km	-18°C 65 km
Young and Novalea	2.5	1	1	1
Beechville	10	1	1	1
Bedford	17	1	1	1
Elmsdale	42	1	1	1
Windsor	66	1	1	2
Chester	67	1	1	2
Mahone Bay	87	1	1	2
Truro	94	1	1	2
Kentville	105	1	2	2
Bridgewater	105	1	2	2
Sheet Harbour	114	1	2	2

If these vehicles were driven in -7°C conditions with cabin heating on, the advertised range could be expected to decline about 25% to about 98 km, meaning that trips to or from Kentville (105 km), Bridgewater (105 km), or Sheet Harbour (114 km) would probably require a charge during the commute in order to reach the destination. In more extreme conditions of -18°C, all vehicles driven from beyond Elmsdale would probably require a charge during the commute.

The need to increase the frequency of charging will be required for all in-use electric vehicles during periods of extreme cold whether or not they use cabin-heating, regardless of the distance travelled. This may have other implications; for example:

- The additional demand for electricity for charging BEVs would occur during the time of year when Nova Scotia Power faces its greatest demand for electricity. The additional demand could occur at any time throughout the day and night.
- Pre-heating the vehicle and battery may reduce the need for cabin-heating in some short-distance journeys and reduce the effect of low temperatures on the batteries; however, this will increase demand for electricity before the journey.
- There will be a demand for additional charging stations in shared parking lots, both public and private, to allow all vehicles to recharge for the next part of their journey.
- Long-distance commuters may be forced to add considerable time to their journey if required to wait for other commuters to charge their vehicles at road-side charging stations.

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<sup>8</sup> The impact of cold-weather driving is based on the report by Meyer et al. (2012) for Transport Canada as opposed to that shown for the Nissan Leaf in Figure 4. This decision was taken because the results in Figure 4 give no indication as to the trip length, cabin conditions, road conditions, or the age of the battery, whereas those found in the Transport Canada report are under controlled, repeatable conditions.

### 3.2 Charging infrastructure

All vehicles, both electric and gasoline, require a readily available source of energy. Gasoline vehicles (CVs, HEVs, and PHEVs) all have the advantage of a well-established network of fuel stations throughout the province. On the other hand, BEVs can be recharged only where there is a mains outlet, such as a residence, charging stations, and public and private parking lots that offer spaces to charge them.

There are a number of different types of Electric Vehicle Supply Equipment (EVSE or simply chargers (Berman, 2014a)) on the market. In Table 9, five different types of chargers are listed, from low-cost, slow-charge units intended for residential use (AC Level 1) to high-cost, fast-charge units designed to operate in commercial conditions (DC Level 2). The installed price includes the cost of the charger, materials, labour (electrician and other), transformer (DC charging only), and permitting (Agenbrood & Holland, 2014).

**Table 9: Types and characteristics of Electric Vehicle Supply Equipment (Bohn, 2013)  
Prices in U.S. dollars (from (Agenbrood & Holland, 2014))**

Charging Level	Setting	Power supply	Rating (typical)	Installed price
AC Level 1	Residential or Parking lot	120VAC/20A (16A continuous)	1.7 kW	\$650-\$1,800
AC Level 2 (minimum)	Residential or Parking lot	208/240VAC/20A (16A continuous)	3.4 kW	\$3,550-\$7,500
AC Level 2 (maximum)	Commercial	208/240VAC/100A (80A continuous)	19.2 kW	\$5,300-\$13,150
DC Level 1	Commercial	208/480VAC ~20A-200A AC	40 kW	\$29,650-\$80,400
DC Level 2	Commercial	208vac/480VAC ~20A-400A AC	100 kW	

The time taken to recharge a vehicle depends on the state of the battery when the charge begins and its capacity. For example, the BMW i3's battery (18.8 kWh capacity) can be charged to 80% capacity in less than 30 minutes using a DC charger (50 kW) or between 6 to 8 hours with an AC charger (1.9 kW to 2.5 kW) (BMW, n.d.).

Although a BEV can be charged anywhere there is an available supply of electricity, the time required to recharge is best done where the vehicle is idle for lengthy periods of time, such as at the owner's residence or place of work. This requires the installation of EVSEs at either or both of these locations:

- If the BEV is not supplied with an EVSE or the EVSE is considered inadequate for the application, the user will be responsible for purchasing and installing the EVSE (Berman, 2014a). This will add to the overall cost of the vehicle.
- Owners of a BEV who park their vehicle on the street (as opposed to in a garage or private driveway) would need either to run a charging cable from their home to the vehicle or to install

a curbside EVSE. Vehicles parked beyond the range of the charging cable or curbside EVSE would require access to other charging infrastructure.

- EVSEs installed in public and private parking-lots could be expected to experience greatest demand during periods of sub-zero temperature driving-conditions. If the parking lot had insufficient chargers, BEV drivers would have to coordinate the recharging of their vehicles throughout the day.
- The cost of recharging in a parking lot would be a function of the total number of vehicles charged in a year, the cost of purchasing and installing the EVSE, and the cost of electricity over the lifetime of the charger. This would also affect the time required to recoup the cost of the charging facilities. Without the promise of sufficient revenue, the parking-lot owner may decide not to install any charging facilities, install a less-expense charger with a lower-rate (meaning fewer vehicles could be charged during periods of peak demand), or install a single high-rate charger (requiring owner-coordinated charging).

### **3.3 Electricity supply – Uncoordinated charging**

The substantial addition of load to any distribution grid can impact the grid's demand profile, voltage profile, and voltage unbalance. Results from numerous simulations have demonstrated that the negative effects of electric vehicle (i.e., both BEV and PHEV) integration were particularly significant in systems without coordinated charging:<sup>9</sup>

**Demand Profile.** With respect to demand profile, literature suggests that the biggest impact will be seen at the distribution transformer level (Gong, Midlam-Mohler, Marano, & Rizzoni, 2012). Further, across all simulations, uncoordinated charging led to significant increases in daily peak energy consumption, as EV owners were simulated charging their vehicles when reaching home (Gong, Midlam-Mohler, Marano, & Rizzoni, 2012; Tuan, Le Pivert, Saheli, & Beaude, 2012; Leemput, Van-Roy, Olivella-Rosell, Driesen, & Sumper, 2015). Additionally, the increased load, even if off-peak, could result in decreased equipment life, particularly given the relationship between transformer temperature and insulation degradation.

By simulating the connection of up to six electric vehicles on a 25 kVA distribution transformer serving six households, significant decreases in equipment life in instances of uncoordinated charging were demonstrated (Gong, Midlam-Mohler, Marano, & Rizzoni, 2012). The worst case scenario studied was simultaneous charging of all vehicles at 7pm, when the extra load associated with the EVs was coincident with peak load, significantly increasing the temperature of the transformer, resulting in insulation life of less than six months, compared with the normal 20.5 year operating lifespan (Gong, Midlam-Mohler, Marano, & Rizzoni, 2012). The report concluded that the impact on transformer life could be mitigated through the use of smart metering and coordinated charging (Gong, Midlam-Mohler, Marano, & Rizzoni, 2012).

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<sup>9</sup> Coordinated charging implies some form of centralized control, whereby the process of charging has the minimum impact on the system while meeting the electric vehicles' charging requirements. The coordination is usually achieved through using a "smart grid" which allows communications between different households (each consisting of appliances, one or more electric vehicles, a home energy management system controller, and a smart-meter) and a centralized load-controller.

**Voltage Profile.** Here, voltage profile refers to the magnitude of voltage seen at the residential load. For safe operation of appliances and electronics, utilities typically adhere to an electricity supplier's voltage-magnitude standard (for example, see (Hydro Quebec, 2015)). This standard requires provision of electricity within a bandwidth of voltages considered acceptable for end-use committing to minimum and maximum voltages within the tolerances of end-use devices. Operation outside of these parameters can cause unsafe operating conditions and result in significant appliance damage.

The simulation of a rural distribution grid with ten electric vehicles connected to individual household chargers (i.e., slow charging) and six electric vehicles connected to public charging-stations (i.e., fast charging) resulted in sustained (i.e., three hours) voltages of less than 95% of recommended voltages during uncoordinated on-peak charging in the distribution grid (Tuan, Le Pivert, Saheli, & Beaude, 2012). The results were corroborated in a simulation where uncoordinated charging resulted in worst-case voltages of less than 75% and typically observed voltages less than 85% of recommended voltages throughout the simulation, affecting each of the simulated households (Leemput, Van-Roy, Olivella-Rosell, Driesen, & Sumper, 2015).

**Voltage Unbalance.** Voltage unbalance refers to differences in voltage magnitude across the phases of a system. In a distribution system, voltage unbalance can be the result of uneven distribution of charging single-phase loads within the system (i.e. connecting and disconnecting a number of electric vehicles served by a single-phase circuit).

The simulation of a 400 kVA feeder with 39 residential single-phase households saw distribution transformer load doubling and grid losses quadrupling when the penetration of electric vehicles reached 100% (i.e., one plug-in vehicle per household) (Leemput, Van-Roy, Olivella-Rosell, Driesen, & Sumper, 2015). If significant numbers of EVs were concentrated on a single phase in a distribution system, the associated large intermittent load could result in voltage unbalance conditions within the system (Bishop, 2008).

The results of this research highlights the need for the deployment of a smart-metering system in advance of large-scale electric-vehicle uptake in a community.

### **3.3.1 Nova Scotia**

An increase in the number of electric vehicles in Nova Scotia would, at first glance, be an attractive proposition to Nova Scotia Power as it would be a way of increasing its revenues. However, there will be issues that need to be addressed by NSP. Given a sufficiently large uptake in electric vehicles, the potential grid impacts, including changes to demand profile, voltage profile, and voltage unbalance could have significant impact in Nova Scotia, particularly with its large rural population and the associated rural distribution grids, including the 69 kV transmission grid in the south-western area of the province.

The effects of charging electric vehicles on the provincial grid would depend on the number of vehicles being charged, the charge rate, and when the charging took place. For example, Table 10 shows the effect of adding between 10 and 100,000 electric vehicle EVSEs (typically rated between 3.3 kW to 6.6 kW (PlugInCars, 2015)) to the grid – the maximum hourly demand would

range between 33 kW to 660 MW. Adding an additional 660 MW of load to the grid during the evening peak could be a challenge, especially during the winter months.

**Table 10: Range of additional hourly demand**

Number of vehicles	Hourly demand (MW)	
	3.3 kW charge rate	6.6 kW charge rate
10	0.033	0.066
100	0.33	0.66
1,000	3.3	6.6
10,000	33	66
100,000	330	660

## 4 Affordability

In the context of this report, affordability refers to payment for the cost of driving within the limits of a budget (Hughes & Ranjan, 2013).

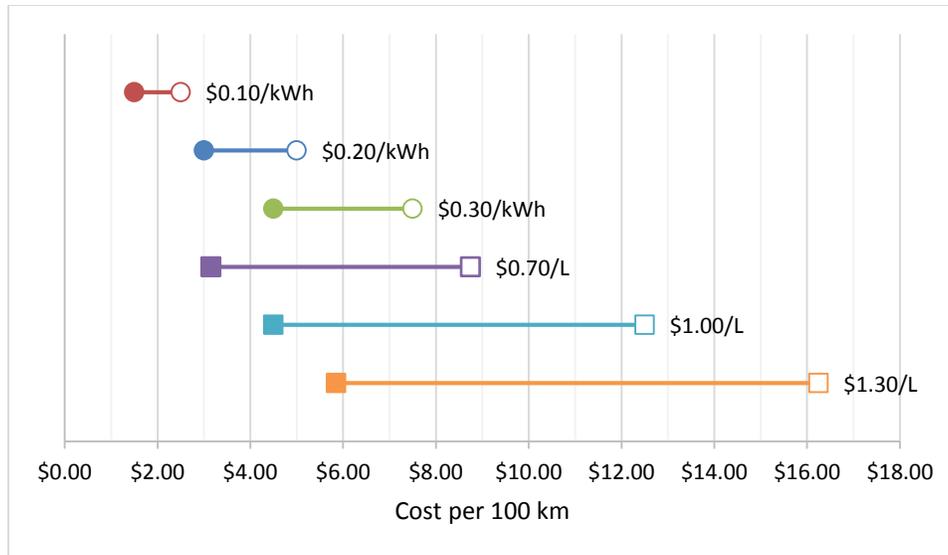
The cost of driving can be discussed in a number of different ways. Perhaps the most common is to consider the cost of fuel to drive 100 km, usually expressed price-per-litre (such as L/100 km for liquid fuels) or the price-per-kilowatt-hour (typically kWh/100km for electricity). The total cost is determined by the price of the fuel set by the energy supplier and any regulatory bodies, the distance driven, and the vehicle’s fuel consumption over the distance.

Another approach is to take the annual operating costs (including the cost of fuel) and the lifetime cost of the vehicle into consideration.

### 4.1 Energy cost per 100 kilometre

In Figure 7, the cost of driving 100 km is compared for electricity and liquid fuels. The energy cost ranges from \$0.10/kWh to \$0.30/kWh for electricity and \$0.70/L to \$1.30/L for petroleum fuels, while the energy consumption varies from 15 kWh/100 km to 25 kWh/100km for electric vehicles (BEVs and PHEVs) and 4.5 L/100 km to 12.5 L/100 km for liquid-fuel vehicles (CVs, HEVs, and PHEVs). The figure shows that (not surprisingly) the cost of driving is influenced by the cost of the fuel and the vehicle’s efficiency.

For example, driving a BEV a distance of 100 km at \$0.20/kWh would cost between \$3.00 (15 kWh/100km) and \$5.00 (25 kWh/100km), whereas the cost driving a CV at \$1.00/L over the same distance is between \$4.50 (4.5 L/100km) and \$12.50 (12.5 L/100km). In this case, driving an efficient CV could be less expensive than driving a less-efficient BEV.



**Figure 7: Cost per 100 km for electric and liquid-fuel vehicles**  
**Electric efficiency: 15 kWh/100 km (solid circle) to 25 kWh/100 km (empty circle)**  
**Liquid-fuel efficiency: 4.5 L/100 km (solid square) to 12.5 L/100 km (empty square)**

The overall per-kilometre cost may be influenced by other factors, including:

**Time-of-use pricing.** The cost of electricity may vary throughout the day, meaning that the total cost of the electricity used by the vehicle may not be constant as suggested in Figure 7.

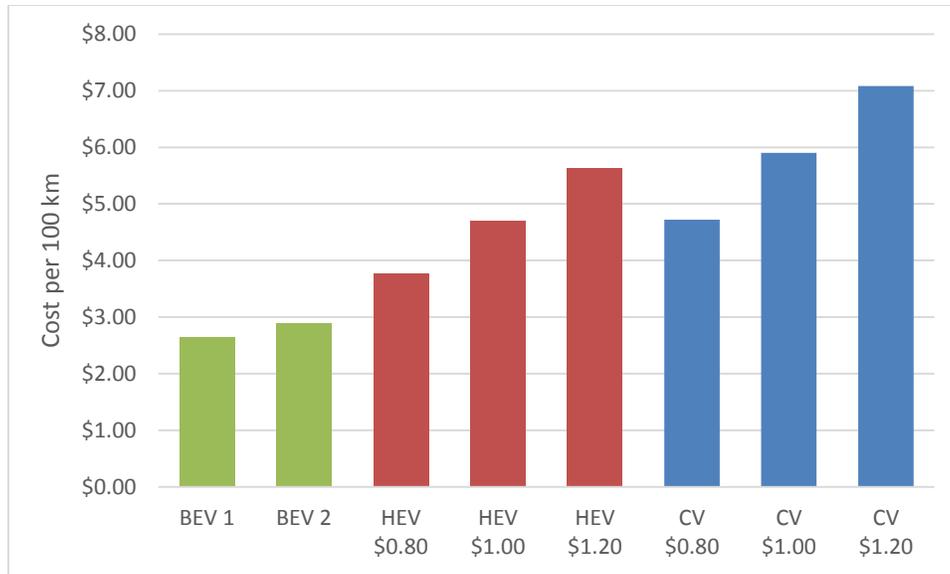
**Auxiliary services.** The total electricity required for the trip may exceed the expected kWh/km. For example, in cold weather, additional electricity may be required for cabin-heat supplied by the vehicle’s battery or a pre-heated storage-heater.

**Taxes.** The per-kilometre cost of a liquid fuel often includes a road tax; these taxes are typically not collected from users of electric-vehicles, thereby making electric vehicles appear less costly to operate.

#### 4.1.1 Nova Scotia

One of the arguments for electric vehicles in Nova Scotia is that they are considerably less expensive to operate than hybrid and conventional vehicles because of the high cost of gasoline. The data used for Figure 8 illustrates this – the cost of the energy needed to drive 100 km in a Nissan Leaf (BEV 2) charged at NSP’s residential rate (\$0.15694/kWh) is between about three-quarters to half for the Prius (HEV) and about 60% to 40% for the Mirage (CV), for gasoline costs between \$0.80 and \$1.20/litre.<sup>10</sup>

<sup>10</sup> NSP’s 2015 residential rate consists of an energy charge (\$0.14251/kWh) and the Fuel Adjustment Mechanism Actual Adjustment (\$0.00121/kWh) and Balance Adjustment (\$0.00575/kWh) charges, giving a total of \$0.14947/kWh. To this, the 5% HST is applied, making the residential rate \$0.15694/kWh.



**Figure 8: Fuel costs for driving 100 km in Nova Scotia**  
**CV (Mirage at \$0.80/L, \$1.00/L, and \$1.20/L)**  
**HEV (Prius at \$0.80/L, \$1.00/L, and \$1.20/L)**  
**BEV 1 (BMW i3) and BEV 2 (Nissan Leaf) at \$0.15694/kWh**

As Table 11 shows, the differences become more apparent when considering the annual fuel costs for driving distances of 10,000 km, 20,000 km, and 30,000 km.

**Table 11: Fuel costs for driving various distances**

Distance (km)	BEV 1	BEV 2	HEV \$0.80	HEV \$1.00	HEV \$1.20	CV \$0.80	CV \$1.00	CV \$1.20
10000	\$264	\$289	\$376	\$470	\$564	\$472	\$590	\$708
20000	\$527	\$578	\$752	\$940	\$1,128	\$944	\$1,180	\$1,416
30000	\$791	\$866	\$1,128	\$1,410	\$1,692	\$1,416	\$1,770	\$2,124

## 4.2 Annualized costs

The annualized cost attempts to capture the total, annual cost of owning and operating a vehicle by tallying annual expenses such as the cost of fuel, insurance, maintenance, and repayments.<sup>11</sup>

The base prices for the vehicles considered in this report are shown in Table 12.

<sup>11</sup> The annual repayment is obtained from:

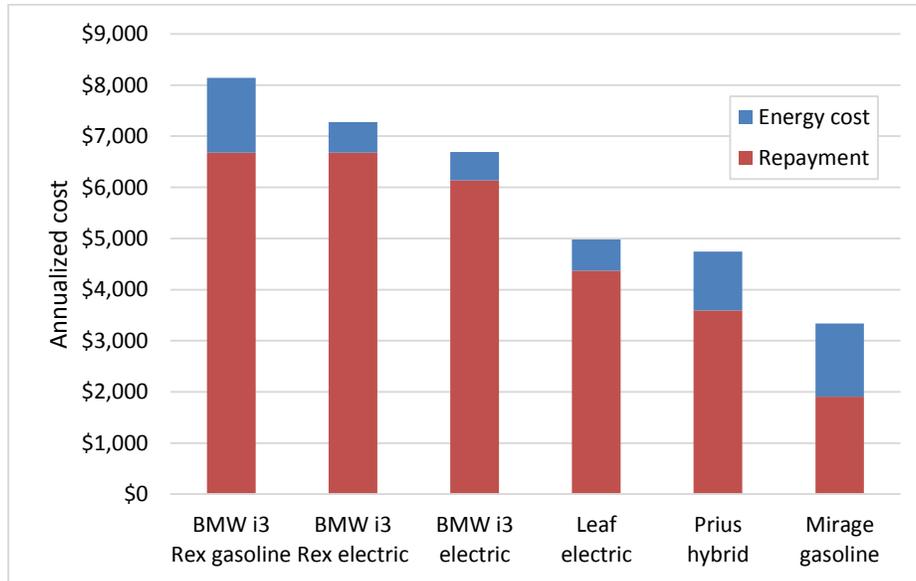
$$Cost \times \frac{r}{1 - (1 + r)^{-t}}$$

Where *Cost* is the total cost of the vehicle, *r* is the discount rate, and *t* is the amortization period, in years.

**Table 12: 2015 vehicle base-prices (prices in Canadian dollars)**  
 (BMW, 2015b; BMW, 2015a; Mitsubishi Motors, 2015; Nissan, 2015; Toyota, 2015b; Toyota, 2015a)

Vehicle	Base price
Mitsubishi Mirage	\$13,948
Toyota Prius	\$26,305
Nissan Leaf	\$31,998
Toyota Prius Plug-in	\$35,905
BMW i3 BEV	\$44,950
BMW i3 REX	\$48,950

Figure 9 shows the annualized repayment and fuel costs for each vehicle, assuming the vehicle is purchased at the base-price with an interest rate of 2%, driven the Nova Scotian average of 22,100 km a year (NRCan, 2015d) for eight years with a 55% city and 45% highway split, and at a cost of \$0.15/kWh and \$1.10/litre. As the annualized costs decline, the cost of energy becomes more significant; for example, about 8.3% of the BMW i3 BEV’s cost is for fuel (electricity), whereas it is about 43% of the Mirage’s total cost. Despite this advantage, the Mirage’s annualized cost is about half that of the BMW i3 because of its lower purchase price.



**Figure 9: A comparison of annualized vehicle costs (BMW i3 Rex: gasoline only or electric only)**

Between January 2010 and March 2015, the average monthly sales of passenger cars and trucks in Nova Scotia were split almost equally, while the average price paid for a truck (which includes minivans, sports-utility vehicles, and light trucks) was almost \$12,000 more than for a passenger car (see Table 13).

**Table 13: Average monthly new vehicle sales and price in Nova Scotia (January 2010 to March 2015) (Statistics Canada, 2015b)<sup>12</sup>**

Vehicle type	Vehicles sold per month	Average price
Passenger cars	2,079	\$24,188
Trucks	2,009	\$35,874

Assuming the same parameters as those used in Figure 9, if a Mirage was purchased for \$24,188, the annualized cost would be \$4,744, which is slightly less than the annualized cost of the Leaf at \$4,979. However, even if the Leaf could be purchased for its base price of \$31,998, the difference in base prices would be about \$7,800, potentially deterring some buyers.

### 4.3 Road taxes

The affordability of electricity is a commonly used argument for driving an electric vehicle rather than a conventional one (for example, see (Campbell, 2015; Calvi, 2015)). However, simply comparing the cost of electricity and the cost of gasoline is misleading since the cost of gasoline typically includes a number of road-related taxes which are not applied to electricity. This means, amongst other things, that in many jurisdictions BEVs do not pay for their usage of the road network.

The subject of the collection of road taxes and electric vehicles is discussed further in section 6.4.

#### 4.3.1 Nova Scotia

In Nova Scotia, vehicles using liquid fuels are subject to three levels of taxation: a provincial gasoline fuel tax (a flat rate of \$0.155/L) (Access Nova Scotia, 2015), a federal excise tax on gasoline (a flat rate of \$0.10/L) (NRCan, 2014)), and the 15% Harmonized Sales Tax (HST), which is applied to both the gasoline and the taxes (Finance and Treasury Board, 2015). The provincial gasoline tax is used for the construction and maintenance of highways (Finance, 2010), while roughly half of the federal excise tax is dedicated to funding projects in municipalities (Infrastructure Canada, 2013; Infrastructure Canada, 2014).

If these taxes were removed, the price of gasoline would fall considerably, as shown in Table 14. The rightmost column is the price of gasoline without taxes, the three middle columns are the applicable taxes (the federal gasoline excise tax and provincial gasoline tax) and the HST (applied to the price of gasoline and the federal and provincial taxes), while the leftmost column is the pump-price of the gasoline. At \$0.80/litre, about 45% of the cost of gasoline is for taxes, whereas at \$1.20/litre, taxes account for about one-third of the price.

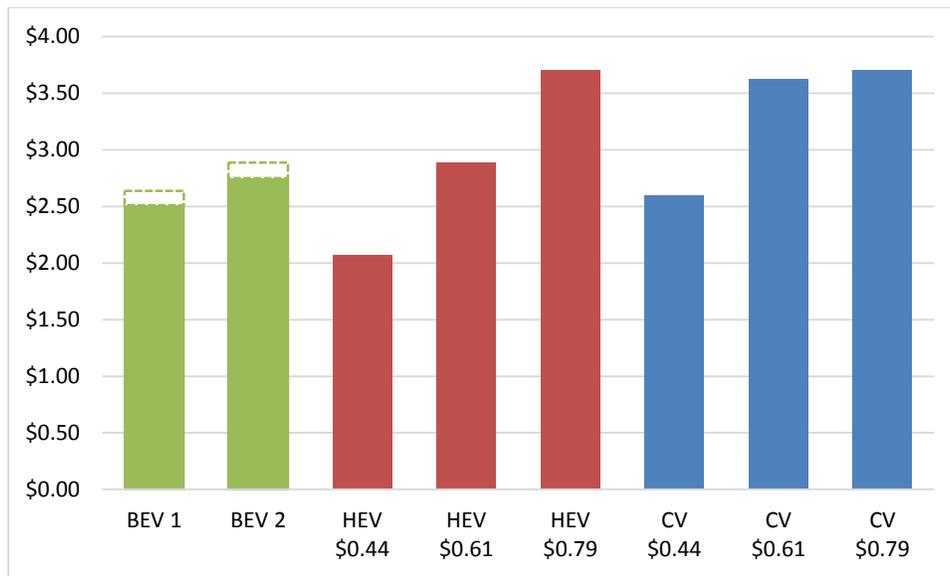
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<sup>12</sup> Trucks include minivans, sport-utility vehicles, light and heavy trucks, vans, and buses.

**Table 14: Cost of gasoline with and without taxes**

Gasoline price with taxes (\$/L)	Taxes (per litre)			Gasoline price without taxes (\$/L)
	HST (15%)	Provincial gasoline	Federal Excise	
\$0.80	\$0.104	\$0.155	\$0.10	\$0.44
\$1.00	\$0.130	\$0.155	\$0.10	\$0.61
\$1.20	\$0.157	\$0.155	\$0.10	\$0.79

If these taxes were not applied to gasoline, its price would fall, making the cost of fuel for HEVs and CVs more competitive with that of electricity; the fuel costs associated with driving 100 km under combined-driving conditions are shown in Table 12.



**Figure 10: Cost of driving 100 km in Nova Scotia without fuel taxes  
BEV 1 (BMW i3), BEV 2 (Nissan Leaf), HEV (Prius), and CV (Mirage)**

**BEV 1 and BEV 2 without (solid green) and with 5% HST (solid green and dashed line)**

At present, Nova Scotia does not apply any form of road tax to electric vehicles (the 5% HST is not a road tax). As a result, BEVs are able to use Nova Scotia’s road network without charge.

## 5 Acceptability

For the purpose of this report, acceptability refers to the greenhouse gas emissions associated with driving a vehicle.

### 5.1 Emissions

NRCan’s 2015 Fuel Consumption Guide lists the CO<sub>2</sub> emissions associated with BEVs as zero grams of CO<sub>2</sub> per kilometre. While there are no CO<sub>2</sub> *Environment*<sub>OUT</sub> flows from the BEV itself, the process of generating electricity does, in many jurisdictions, result in CO<sub>2</sub> *Environment*<sub>OUT</sub> flows.

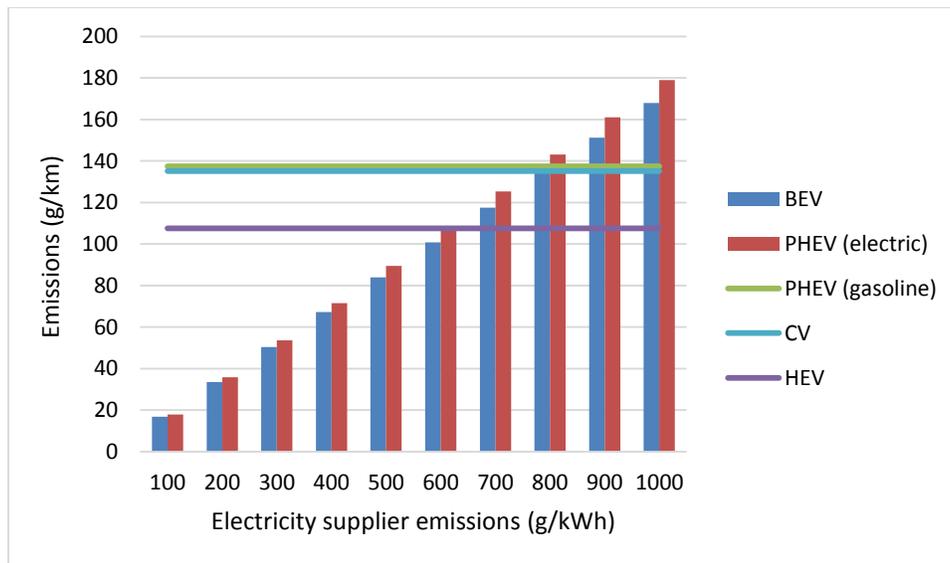
The emissions associated with both liquid-fuel and electric vehicles come primarily from the combustion of hydrocarbons. In a liquid-fuel vehicle (CV, HEV, or PHEV), the combustion of

gasoline results in three different greenhouse gases: carbon dioxide, methane, and nitrous oxide (see Table 15); the sum of these emissions is often referred to as CO<sub>2</sub>e or carbon-dioxide equivalent. An electricity supplier's emissions intensity (CO<sub>2</sub>e/kWh) depends upon its energy mix.

**Table 15: Greenhouse gases per litre of gasoline (Canada, 2013)**

Greenhouse gas	kg/L	Percent
Carbon dioxide (CO <sub>2</sub> )	2.289	99.993%
Methane (CH <sub>4</sub> )	3.20×10 <sup>-4</sup>	0.014%
Nitrous oxide (N <sub>2</sub> O)	6.60×10 <sup>-4</sup>	0.029%
Total (CO <sub>2</sub> e)	2.2900	

Figure 11 shows the greenhouse gas intensity (grams of CO<sub>2</sub>e per kilometre) associated with the four vehicle categories. The emissions per kilometre from both the BEV and PHEV (running on electricity) vary, from less than 20 g CO<sub>2</sub>e/km to almost 180 g CO<sub>2</sub>e/km, depending on the greenhouse gas intensity of the electricity supplier (grams of CO<sub>2</sub>e per kilowatt-hour) and the vehicle's electricity intensity (kilowatt-hours per kilometre), while the emissions of the PHEV (running on gasoline), HEV, and CV are constant, determined by the vehicle's fuel intensity (litres per kilometre). The emissions associated with PHEV (gasoline) and CV are almost identical. Figure 11 refers to combined driving conditions (i.e., 55% city and 45% highway) as NRCan only reports the electricity intensity for PHEVs for combined driving only, not city or highway.



**Figure 11: Emissions by vehicle type (combined-driving only)**

**PHEV (electric) are the emissions from the PHEV when operating on electricity only**

**PHEV (gasoline) are the emissions from the PHEV when operating on gasoline only**

The emissions per kilometre from an electric vehicle will vary over a year for a number of reasons, including:

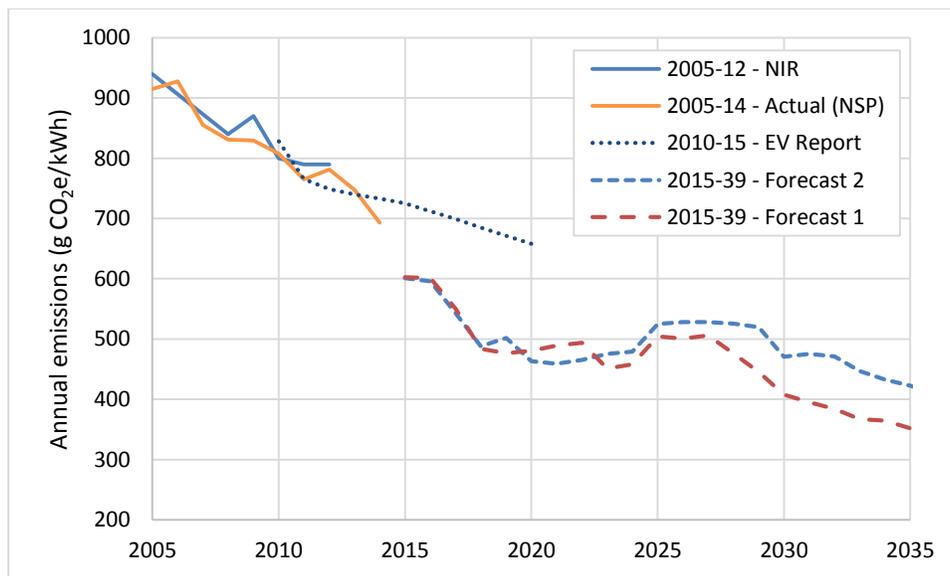
**Supplier energy mix.** The electricity supplier’s energy mix can vary throughout the day, resulting in different emissions intensities. The emissions intensity of the electricity at the time of charging will be reflected in the vehicle’s emissions.

**Auxiliary services.** In addition to a vehicle’s motive energy requirements, additional energy may be required for auxiliary services such as cabin heating.

**Types of journeys.** BEVs can be optimized to operate better in one set of conditions than another. For example, most BEVs listed in the Fuel Consumption Guide have a lower per kilometre electric-intensity for cities than highways; whereas the Tesla vehicles are the opposite (see Table 7).

### 5.1.1 NSP-specific – changes over next decade

Over the past decade, NSP has made considerable reductions in its greenhouse gas emissions (see Figure 12). The reductions can be attributed to an increase in renewables (especially wind), a greater reliance on natural gas, and a reduction in demand. Additional declines in emissions are expected in 2017 with the replacement of electricity from existing NSP’s coal-fired generating stations with hydroelectricity from Muskrat Falls in Newfoundland and Labrador.<sup>13</sup> If NSP’s forecasts are correct, emissions in 2015 will be one-third lower than in 2005, a decline from 915 g CO<sub>2</sub>e/kWh to 603 g CO<sub>2</sub>e/kWh. When electricity from Newfoundland and Labrador is supplied to Nova Scotia Power, emissions are expected to be about half of what they were in 2005.



**Figure 12: NSP’s emissions – actual and forecast**

**Data sources: 2005-12 NIR (Canada’s National Inventory Report to the IPCC); 2005-14 Actual (NSP’s recently released emissions data); 2010-20 EV Report (forecast emissions from NSP in 2010); 2015-35 Forecast 1 and Forecast 2 (NSP’s long-term forecast to 2039)**

<sup>13</sup> Construction delays means that first power from Muskrat Falls, originally forecast for December 2017 (Newfoundland and Labrador, 2015), is now not expected until sometime in 2018 (CBC, 2015).

### 5.1.2 Emissions per vehicle

NSP's average annual emissions are forecast to decline from about 700 g CO<sub>2</sub>e/kWh in 2014 to about 450 g CO<sub>2</sub>e/kWh by 2030. Assuming no further technological advances in any of the vehicles considered in this report, this means that electric vehicles will become increasingly more environmentally acceptable than the best conventional and hybrid-electric vehicles, as shown in Figure 13.

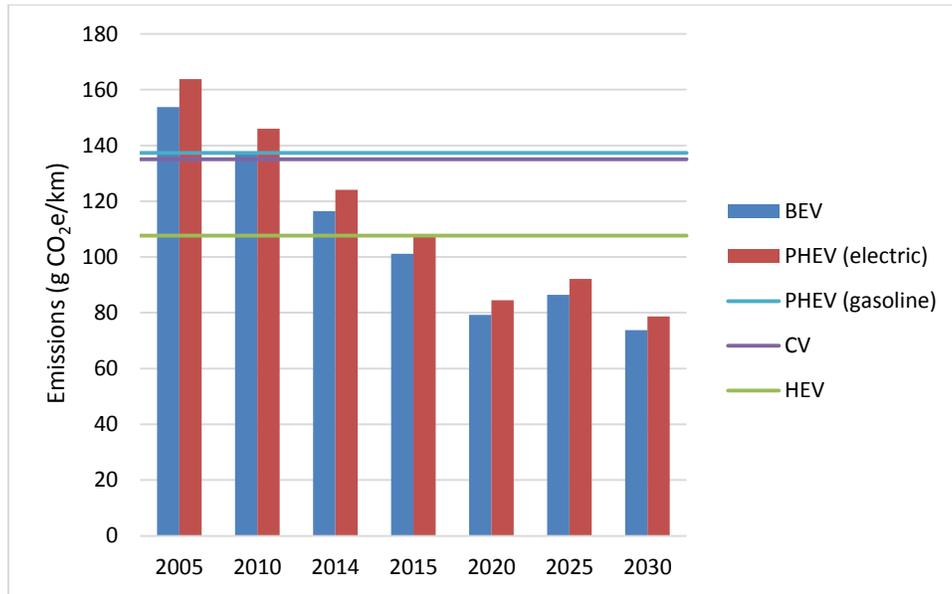
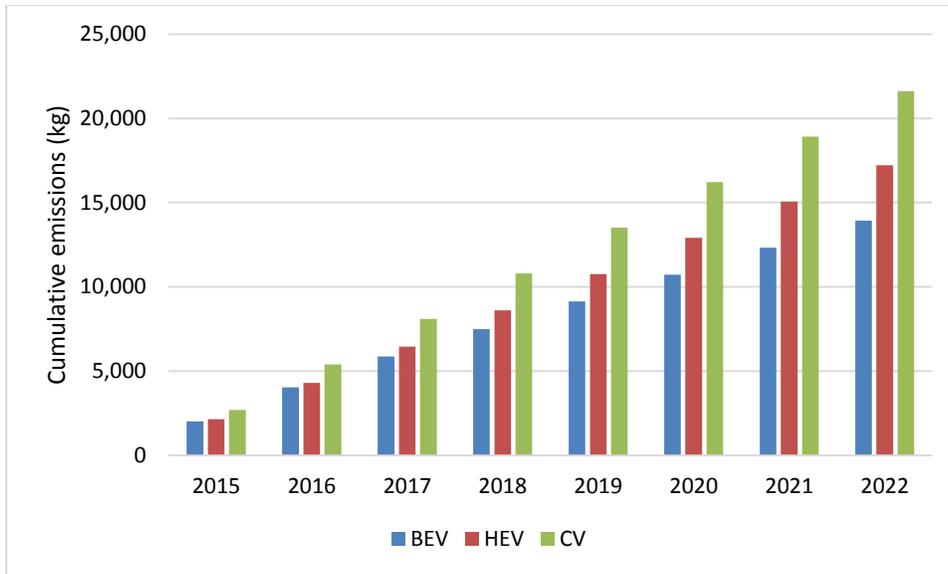


Figure 13: Emissions by vehicle type (combined only)

### 5.1.3 Cumulative emissions

A vehicle's cumulative emissions are the emissions produced over its lifetime while operating. For example, Figure 14 shows the cumulative emissions associated with driving a BEV (BMW i3), an HEV (Toyota Prius), and a CV (Mitsubishi Mirage) for eight years at 20,000 km a year starting in 2015 in Nova Scotia. During this time, NSP's forecast emissions fall from 602 g/kWh to 480 g/kWh (the emissions from the HEV and CV are assumed to be constant at 108 g/km and 135 g/km, respectively). By 2022, the HEV and CV would have emitted an additional 3.2 tonnes and 7.7 tonnes of CO<sub>2</sub>e compared with the BEV, respectively.



**Figure 14: Cumulative emissions from a BEV, HEV, and CV in Nova Scotia (2015-2022)**

Table 16 shows the difference in emissions for different distances in Nova Scotia for the 2015-2022 timeframe. In all cases, the BEV has lower emissions; for example, if a BEV and HEV were driven 10,000 km a year, the difference in total emissions would be 1.64 tonnes, whereas a CV driven 30,000 km a year would have about 11.5 tonnes more total cumulative emissions than a BEV driving the same distance over the eight year period.

**Table 16: Difference in total cumulative emissions for different distances in Nova Scotia (2015-2022)**

BEV vs.	Distance driven		
	10,000 km	20,000 km	30,000 km
HEV	1.64 t	3.28 t	4.93 t
CV	3.84 t	7.68 t	11.50 t

If the decline in NSP’s emissions continues as projected into the 2020s and 2030s, these differences would become more pronounced, given the same vehicles (see Table 17). During this time period, a HEV driven 10,000 km would emit 2.05 tonnes more than a BEV, while the emissions from a CV driven 30,000 km would exceed those of a BEV by about 12.75 tonnes.

**Table 17: Difference in total cumulative emissions for different distances in Nova Scotia (2020-2027)**

BEV vs.	Distance driven		
	10,000 km	20,000 km	30,000 km
HEV	2.05 t	4.10 t	6.15 t
CV	4.25 t	8.50 t	12.75 t

## 6 Discussion

### 6.1 Electric-vehicle penetration

In 2012, there was an estimated 128.7 million cars in the United States (both conventional-fuel and alternative-fuel) (EIA, 2015). Of the roughly 4.73 million alternative-fuel vehicles, almost 95% were either ethanol flex-fuel vehicles or HEVs, while PHEVs and BEVs made up 1.2% and 0.8%, respectively (see Table 18). In terms of the total number of cars in the United States, BEVs and PHEVs were less than 0.08% of the total. In 2013, about half of the BEVs in the United States were registered in California (EIA, 2014).

**Table 18: Alternative-vehicle stock in the United States – Reference scenario (EIA, 2015)  
(Millions of vehicles)**

Car type	2012 (actual)		2020 (estimated)		2030 (estimated)	
	Total	Percent	Total	Percent	Total	Percent
Propane ICE	0.03	0.6%	4.48	45.4%	7.40	48.4%
Natural Gas ICE	0.03	0.6%	0.00	0.0%	0.15	1.0%
Ethanol-Flex Fuel ICE	2.39	50.6%	4.43	44.9%	5.73	37.5%
Plug-in 10 Gasoline Hybrid (PHEV)	0.02	0.4%	0.08	0.8%	0.09	0.6%
Plug-in 40 Gasoline Hybrid (PHEV)	0.04	0.8%	0.34	3.4%	0.82	5.4%
100-Mile Electric Vehicle (BEV)	0.04	0.8%	0.21	2.1%	0.49	3.2%
200-Mile Electric Vehicle (BEV)	0.00	0.0%	0.05	0.5%	0.07	0.5%
Electric-Gasoline Hybrid (HEV)	2.09	44.3%	0.16	1.6%	0.39	2.6%
Other	0.09	1.9%	0.11	1.1%	0.15	1.0%
Total Alternative-Fuel Cars	4.72	100.0%	9.86	100.0%	15.29	100.0%
Total car stock	128.66		131.68		142.3	

The EIA's reference scenario projections to 2020 and 2030 in Table 18 show that the total number of vehicles (both alternative and conventional) will increase, in part because of increased demand for alternative-fuel vehicles. By 2030, the number of BEVs (100 and 200 Mile Electric Vehicles) and PHEVs (Plug-in 40 and Plug-in 10 Gasoline Hybrid Vehicles) will have increased from about 100,000 vehicles in 2012 to almost 1.5 million, most of which are PHEVs. About 1% of the total car stock of 142 million vehicles in 2030 is expected to be BEVs and PHEVs.

### 6.2 Increasing public acceptance of electric vehicles

At present, there are very few electric vehicles on Nova Scotia's roads (Pushkarna, 2015). For the numbers to increase, the public's attitude towards electric vehicles would need to change.

There are five criteria that govern the rate at which innovations, such as the electric vehicle (and like others before it, including electricity, the telephone, and the home computer), are accepted by society (Rogers, 2003; Gourville, 2005):

**Relative advantage** refers to the cost and benefit advantages of the innovative product compared to its existing counterpart – the greater this perception, the greater the relative advantage. The advantages associated with electric vehicles, such as lower greenhouse gas emissions, reduced operating noise, and the convenience of at-home charging, must be

indicative of public reaction and perceived net benefit over CVs. Despite these advantages, opinion polls suggest that they are not sufficient to sway the public in their favour.

A survey of 2,171 individuals in Newfoundland and Labrador (see Table 19) found that only 18% would consider purchasing an electric vehicle. Although 28% had concerns regarding range and battery capacity, most respondents (44%) expressed a high level of uncertainty regarding product capabilities and market readiness.

**Table 19: VOCM Question of the Day (3 March 2015) (VOCM News, 2015)**

Would you ever consider buying an electric vehicle?	Response
Yes, it's better for the environment.	18%
Maybe, if the battery lasted as long as a tank of gas.	28%
No. Wait until they iron out the bugs.	44%
I don't know.	10%

These results are consistent with a Canadian electric vehicle consumer preferences study conducted in 2010 which found that amongst those who indicated a willingness to consider purchasing an electric vehicle, two-thirds would no longer be willing if there was a price premium for electric vehicles (Deloitte, 2011). A further 3% and 5% indicated that the highest premium they would be willing to pay would be \$250 USD and \$500 USD, respectively (Deloitte, 2011).

**Compatibility** of existing values and consumer experiences when applied to the innovation. With electric vehicles, this is the degree to which the driving experience associated with the vehicle is compatible with the consumers driving needs. For electric vehicles to gain broad acceptance, they will need to provide the driver with an equal or superior driving experience to that provided by conventional vehicles.

**Complexity** refers to the behavioural changes associated with adopting the innovation, that is, how difficult or challenging the new technology is to understand and use. An example of the perceived complexity of electric vehicles is the fact that they require a new way to refuel the vehicle, using at-home or public chargers. Reducing complexity means overcoming public concerns of charging with electricity and its safety.

**Trialability** is the ability of a potential adopter to interact and experiment the new product before actually purchasing it. Given that electric vehicles are seen as an innovative technology, trialability means more than a simple test-drive around the block. As an example, in 2010, BMW conducted a leasing experiment in which it provided the opportunity for customers in Los Angeles and New York/New Jersey to lease its MINI E BEV; following participation in the trial activity, 71% of participants indicated an increased likelihood of purchasing a BEV (Turrentine, Garas, Lentz, & Woodjack, 2011). However, in the BMW case, trialability involved signing a one-year lease at \$850 per month – an expensive proposition for some potential adopters. Brief test-drives with owners of electric vehicles are not likely to assuage concerns concerning relative advantage and compatibility.

The BMW study also raised another issue, a strong majority of participants indicated they supplemented their BEV usage with a second car – opting to use a non-electric vehicle in

situations where range was a concern (Turrentine, Garas, Lentz, & Woodjack, 2011). Purchasing a second vehicle as a backup for the electric vehicle could prove to be too expensive for many would-be purchasers.

**Observability** is the opportunity afforded to both the public and potential adopters to observe the product being used. In this respect, electric vehicles are challenging since they look much the same as any other vehicle on the road. In terms of everyday use, observability is likely highest for electric vehicles when charging or using dedicated parking infrastructure.

Public charging stations could be looked upon as a double-edged sword. First, the lack of electric vehicles means that public charging station will be unused for long periods, raising questions as to the use of public funds for its installation. Second, the time to recharge (compared to refueling a conventional vehicle) may be seen as being too long to some observers, especially if there are several vehicles waiting to recharge at the same time (Berman, 2014b).

Other reasons for the limited uptake of BEVs other than the Tesla in 2015 have been suggested. For example, the recent decline in the price of gasoline may have an impact on BEV sales, although the lack of significant marketing on the part of vehicle manufacturers and the promise of new vehicle technology may be contributing factors as well (Arcus, 2015; Kress, 2015).

### **6.3 Subsidies**

Over the past number of years, governments in a variety of jurisdictions around the world have offered subsidies to offset the purchase price of electric vehicles (for details of subsidies and tax incentives in the United States, see (The Car Electric, n.d.)). Arguments for such subsidies and incentives are varied, but often are presented as ways to:

- Support industries that manufacturer electric vehicles or products such as charging stations (Kopperson, Kubursi, Livingstone, Nadeem, & Slykhuis, 2014).
- Meet vehicle emissions targets to protect human health or the environment, or both (Center for Sustainable Energy, 2015).
- Create a demand for electricity (PSE, 2015).
- Present the jurisdiction as an environmental leader (WA DoC, 2012).
- Reduce the need for foreign energy imports (EERE, 2011).
- Encourage electric vehicles to come to a jurisdiction (Sullivan, 2015a).
- Raise the profile of electric vehicles (Campbell, 2015).

#### **6.3.1 Nova Scotia – Charging infrastructure**

Unlike a number of other provinces, the Nova Scotia government does not offer a direct subsidy for the purchase of electric vehicles, although in 2013, it awarded two grants totaling \$47,000, to offset the cost of twelve AC charging stations across the province and a fast DC charging station at the Truro Power Center (NS DOE, 2013). Recipients of an AC charging station are expected to

pay \$1,200 for the installation and are responsible for paying the cost of any electricity consumed for at least a year, estimated at \$1.50 per charge (Sullivan, 2015b).<sup>14</sup>

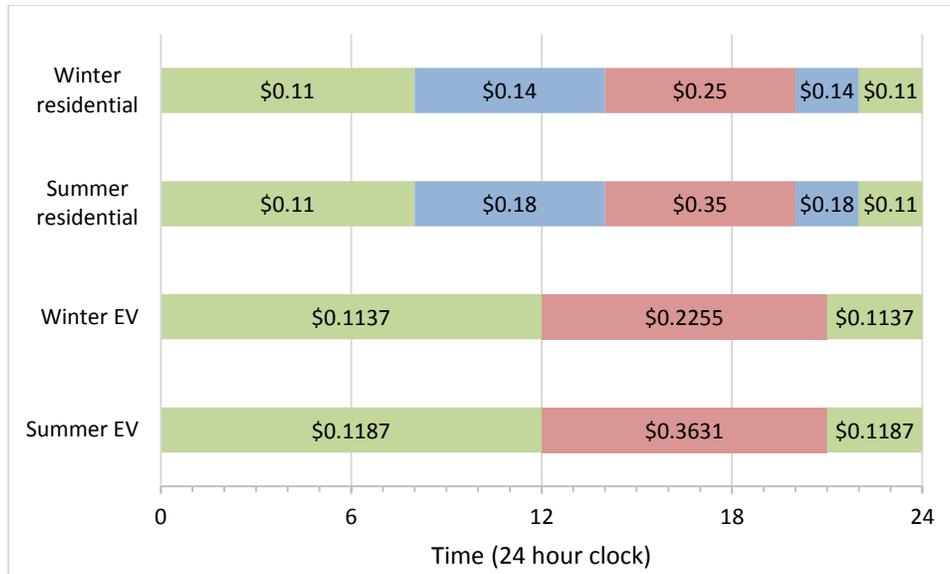
In other jurisdictions, vehicle manufacturers and electricity suppliers are also involved, either directly or indirectly, in the installation of EVSEs as they stand to benefit from the adoption of BEVs and PHEVs. Vehicle manufacturers such as Volkswagen and BMW have announced investments in non-proprietary EVSE infrastructure in the United States (Davies, 2015), while at the same time arguing for additional government support (VW, 2015). On the other hand, Tesla is installing their own stations with proprietary EVSE infrastructure.

The highest concentration of BEVs and PHEVs in the United States is on the Pacific Coast between Washington State and California. In response, and to encourage the uptake of electric vehicles, a network of EVSE stations are being installed along Interstate 5, dubbed the “West Coast Electric Highway” (WCGH, 2014); British Columbia is also involved in the project (WCGH, 2008). The installation of most EVSEs is subsidized by taxpayers (state or local governments) or ratepayers (electricity supply companies), or both. Examples of EVSE support include:

- A \$500 rebate on a Level 2 charger from Puget Sound Energy (PSE, 2015).
- Washington State tax exemption for the installation, repair, alteration, or improvement of EV infrastructure or the sale of property used for EV infrastructure (AFDC, 2014).
- Portland General Electric Company will provide \$14,000 per station for up to 20 D.C. charging stations and \$2,250 per station for up to 40 Level 2 charging stations as Oregon’s portion of the West Coast Electric Highway (PGEC, 2013).
- A residential tax credit of up to \$750 for the installation of alternative fuel recharging infrastructure, including electricity, in Oregon (ODOE, n.d.).
- Most electricity supply companies in California offer a number of different tariff options for residential EV charging, most use interval meters and seasonal TOU billing. For example, an EV owner purchasing electricity from Southern California Edison can be billed using either a single meter and the residential tariff or two meters and two tariffs (residential and EV); the weekday rate structures are shown in Figure 15. In order to encourage off-peak electricity usage, the overnight hours have the lowest cost (California electricity suppliers have a summer peak because of air conditioning).

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<sup>14</sup> The \$1.50 per charge cost appears to be based on a 10kWh charge at NSP’s residential rate of \$0.149/kWh.



**Figure 15: Southern California Edison residential and EV tariffs (SCE, 2015a; SCE, 2015b)**

- By 2025, California plans to have 1.5 million zero-emission vehicles (ZEVs) on its highways to reduce its reliance on petroleum, improve local air quality, and reduce greenhouse gas emissions to 80% below 1990 levels by 2050 (GIWG, 2015). An increase in the number of both BEVs and PHEVs is seen as an integral part of the ZEV action program; in response, electricity suppliers such as PG&E, one of California’s major electricity suppliers, has announced plans for the installation of 25,000 Level 2 and 100 D.C. fast charging stations in northern and central California (PG&E, 2015). The total cost of PG&E’s plan is estimated to be over \$650 million, to be covered by PG&E ratepayers (the estimated cost to residential customers is 70 cents per month between 2018 and 2022 (PG&E, 2015)) (Cole, 2015). If approved by state regulators, PG&E would provide the EVSE free-of-charge to property owners, but retain ownership of the equipment; the maintenance and management of the EVSEs as well as billing would be the responsibility of the property owners, while PG&E would supply the electricity.

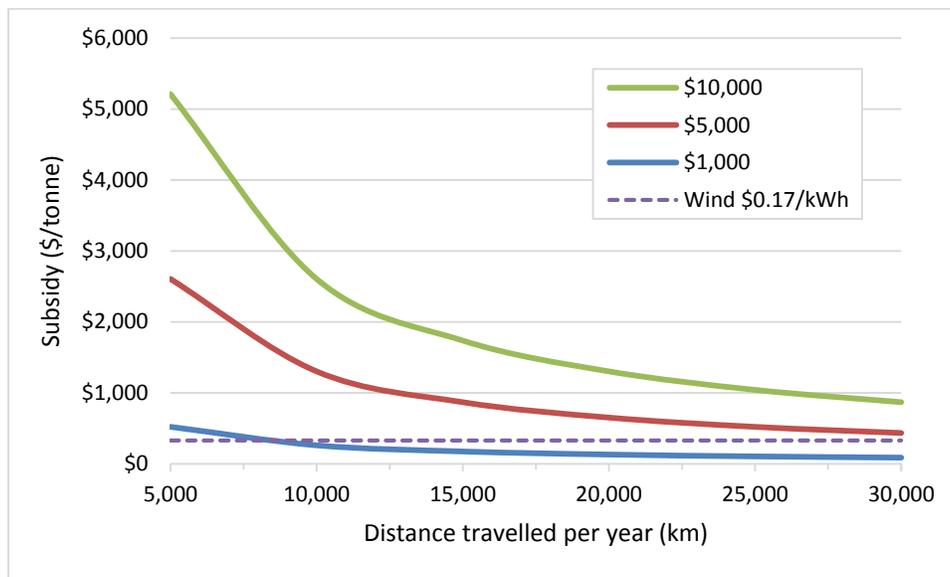
Since neither charging stations nor electricity is free, some EVSE stations are billing drivers for charging their vehicles (Chargepoint, 2015). Prices vary, but are typically calculated by hour and the type of charger; for example, a \$2.00 per hour charge with a 6.6 kWh Level 2 charger amounts to about \$0.30 per kWh. Making electricity freely available to electric vehicle owners has encouraged some BEV and PHEV owners to do a minimum charge at home and then find nearest no-cost charger to charge their vehicle (Berman, 2014c).

### 6.3.2 Nova Scotia – Electric vehicles

One argument for subsidizing BEVs directly in Nova Scotia is that they have lower levels of emissions per kilometre than either CVs or HEVs. While the emissions argument is true, as was shown in Table 16, when it comes to subsidies, it is necessary to select a metric to determine the relative cost of the subsidy; a common approach is to consider the cost per tonne of CO<sub>2</sub> reduction, obtained from the value of the subsidy and the difference in emissions over the operating lifetime of, for example, a CV and an EV.

In Table 16, the difference in emissions between a CV and an EV driven 20,000 a year over an eight-year period (2015-2022) would amount to about 7.68 tonnes of CO<sub>2</sub>. A subsidy of \$1,000 would cost about \$130 per tonne. This value compares favourably with the \$0.17/kWh that Nova Scotians pay to subsidize wind, which amounts to about \$328 per tonne.<sup>15</sup>

Figure 16 shows the amount paid to reduce one-tonne of CO<sub>2</sub> emissions. This amount depends on the distance driven each year (5,000 km/year to 30,000 km/year) over the eight years and the cost of the subsidy per vehicle (\$1,000, \$5,000, and \$10,000 in the example). For example, purchasing an EV (rather than a CV) with a subsidy of \$5,000 would result in a difference of 1.9 tonnes of emissions if the vehicle was driven 5,000 km/year, the equivalent to \$2,600/tonne in subsidies, while the subsidy would amount to \$434/tonne if the same vehicle was driven 30,000 km/year, with 11.5 tonnes fewer emissions than the CV. In either the \$5,000 or \$10,000 case, it would be more cost effective for the province to subsidize wind-electricity than electric vehicles.



**Figure 16: Cost of subsidies (\$/tonne) for a BEV driven different distances (2015-2022)**

Since the difference in emissions between BEVs and HEVs is relatively small, the cost per tonne of emissions reduction is much higher for a HEV than it is for a CV, as shown in Table 20. For example, a HEV driven 20,000 km/yr would emit 3.3 t CO<sub>2</sub>e more than a BEV over eight years, meaning that a subsidy of \$1,000 would cost \$305 per tonne.

**Table 20: Cost per tonne of emissions reduction (BEV vs. HEV) over eight years (2015-2022)**

Subsidy	10,000 km	20,000 km	30,000 km
\$1,000	\$609/t	\$305/t	\$203/t
\$5,000	\$3,045/t	\$1,523/t	\$1,015/t
\$10,000	\$6,091/t	\$3,045/t	\$2,030/t

<sup>15</sup> NSP's average emissions between 2015 and 2022 are estimated to be 518 g/kWh (518 kg/MWh or 0.518 t/MWh). The wind-electricity subsidy of \$0.17/kWh (\$170/MWh) will amount to  $\frac{\$170/MWh}{0.518 \text{ t/MWh}}$  or \$328/tonne over this period.

There is a catch-22 in the subsidy – the lower the subsidy, the less it costs to pay for a tonne of emissions reduction. However, the lower the subsidy, the less of an incentive it is for people to purchase a BEV. Similarly, the cost per tonne of reduction declines the more the vehicle is driven; however, since there is no guarantee of the total distance the vehicle will be driven, it is difficult to predict what the actual reductions (and hence subsidy) would be, especially if the driver opted to use a CV during the winter months.

If the price of an electric vehicle with a subsidy is still beyond the average price Nova Scotians pay for new vehicles, the beneficiaries of any subsidy could be those who could probably afford the vehicle in the first place. This raises the prospect of individuals or groups who were already planning to purchase a BEV or PHEV acting as economic free-riders and using the subsidy to purchase a more expensive vehicle (Johnson, 2005).

While one can make arguments in favour of subsidies for BEVs (from taxpayers and ratepayers), equally strong arguments can be made against subsidies; for example, the need for more urban transit in response to increasing urban densification in Halifax (Stantec, 2013), the decline in automobile use in some major cities (Moss, 2015), and the effects of ageing populations on car use (Newman & Kenworthy, 2011).

#### **6.4 Road taxes**

At present, although a large portion of the cost of many of the charging stations installed in the province are paid for by Nova Scotians, electric vehicles driven on Nova Scotia's road network do not pay road taxes. While there are many arguments against taxing electric vehicles for their road use (including electric vehicles typically have less emissions per kilometre than their conventional counterparts (Built By Michigan, 2015), there are few BEVs on the road (Built By Michigan, 2015), BEVs result in macroeconomic cost savings (Anonymous NSP reviewer, personal communication, 18 December 2015), and they improve energy security (AFDC, 2015)), the fact is road taxes are, as the name suggests, for roads not the environment or potentially improving energy security. As road tax revenues decline due to declining vehicle usage in the United States (Pyper, 2014), a growing number of state legislatures are introducing fees to generate revenues from electric vehicles using state highways (Hartman, 2015).

Given the condition of Nova Scotia's roads, it is reasonable to assume that the province will need to develop an equitable program of road taxes that includes electric vehicles. However, taxing electric vehicles for their use of the province's road network presents two problems. The first is how much to charge for the road use and the second is how to collect the tax.

Gasoline and diesel road taxes are straight-forward to administer and collect since most vehicles purchase their fuel with the applicable taxes already included in the price, from vendors who collect the tax. The electricity used in electric vehicles could be taxed at regulated charging stations designed to collect the tax as part of the sale; however, vehicles charged at an unregulated location (such as a residence or a place of work) cannot be taxed easily at present in Nova Scotia.

Despite this, there are ways in which road taxes can be collected from electric vehicles; for example:

- A one-time charge could be applied to the vehicle when it is sold to a consumer, based on expected road use and life of vehicle. However, this policy would not work for vehicles purchased out-of-province and would be unfair to drivers leaving Nova Scotia to work or travel in other jurisdictions where an electric-vehicle road tax was collected.
- Toll roads could be used to collect road taxes; however, the tolls collected for a toll road are often earmarked for the maintenance of the road being tolled rather than all roads (Lindsey, 2007). Moreover, vehicles not driven on toll-roads would not be subject to the road taxes.
- Many, if not all, electric vehicles have wireless communication capabilities (for example, see (Moritz & Ohnsman, 2013; Nissan, n.d.; Onstar, n.d.)) which could be used for collecting taxes. By relaying the vehicle's odometer information as well as its 17-digit VIN (Vehicle Identification Number) to a central road operations center, the tax could be collected from the owner using, for example, credit card information. This could be done at any charging station with communication facilities. In situations where the charging takes place at a location without communications, the vehicle could store the charging information and relay it to a central road operations center when the opportunity arose.

The above proposals notwithstanding, it is widely agreed that fuel consumption is a poor proxy for road use (Lindsey, 2007). An alternative is to collect a road-usage tax based on, for example, vehicle-type, or the average vehicular road use in the province. A fairer alternative would be to determine the vehicle's actual road use by comparing the vehicle's past and current odometer values, something already done in Nova Scotia during the vehicle inspection (Nova Scotia, 2009). Such a policy could be applied to all vehicles, electric or otherwise, as part of the license renewal process (Built By Michigan, 2015).

## 6.5 Improving energy security

For battery electric-vehicles to improve Nova Scotia's energy security, they must reduce the risk associated with the existing fleet of light-duty passenger vehicles. Broadly speaking, there are three major threats associated with continued use of conventional vehicles in Nova Scotia, all related to the fact that CVs rely on petroleum products:

**Availability.** Although Nova Scotia may have offshore reserves of crude oil (Nova Scotia, n.d.), these must be extracted and shipped to a refinery for processing. The petroleum products that Nova Scotia consumes are neither refined here nor, at present at least, sourced from Nova Scotia.<sup>16</sup>

Relying on petroleum products that have been refined elsewhere is typically not a problem, given the logistics in the petroleum market. However, this does not mean that mistakes won't occur, as Nova Scotians learned late summer when there was an unexpected shortage of gasoline (CBC, 2015).

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<sup>16</sup> Even if Nova Scotia were still to have a refinery that would not guarantee that Nova Scotian crude oil would be refined at it, given that both crude oil and its refined products are fungible. Moreover, one of the reasons that Nova Scotia's refinery was shuttered was its inability to process the increasingly heavier crudes that were appearing on the market at the time.

The risk of a petroleum supply shortfall is very low, given that the likelihood of the event is rare and the vulnerability is low because of the existing supply chain.

**Affordability.** The price of petroleum products is determined by both world oil markets and the refining costs. Over the past 20 years, this has proven to be somewhat volatile; recently, the decision by Saudi Arabia to oversupply the world with oil has seen prices drop markedly (IEA, 2015). How long prices will remain depressed is anyone's guess; for example, continued rising tensions in the Middle East could trigger a price increase, but even this may be short-lived, given the world's overcapacity of supply.

The risk of an increase in the cost of gasoline over the medium-to-long term is moderate to high, not because of Middle East tensions, but due to the likelihood of carbon pricing being introduced in the province, either in the form of carbon taxes or emissions trading.

**Acceptability.** As this report has shown, road transportation is carbon-intensive. The threats associated with anthropogenic climate disruption are expected to be high to very-high over the long-term, making the continued use of carbon-intensive fuels a high risk.

Reducing these risks will require energy policies that *restrict* future road transportation to low-carbon energy sources (Hughes, 2009). This report has shown how, if Nova Scotia Power achieves its 2030 emissions targets, per-kilometer emissions from BEVs will be about half that of CVs (see Figure 13). While the widespread adoption of BEVs would help Canada meet its Paris Agreement commitments, achieving this goal is not without its risks:

**Availability.** BEVs will be a new load for Nova Scotia Power, requiring Nova Scotia Power to upgrade parts of its grid and roll-out a province-wide smart grid. If Nova Scotians increase their use of electricity as a source of low-emissions energy, meeting this demand may become an issue if demand for electricity from new services cannot be met during, for example, the winter peak.

**Affordability.** While the per-kilometer cost of electricity is less than that of liquid fuels, BEVs are, at present, more expensive than CVs. If the CV-BEV cost differential cannot be addressed, there is a risk that transportation emissions will be higher than expected.

**Acceptability.** Despite the anticipated decline in Nova Scotia Power's emissions, there are still acceptability risks. For example, to ensure that BEVs can be used for year round transportation needs, they will require a method of cabin-heating and sufficient storage to avoid using CVs for winter driving. If this cannot be done, there would be a risk that the emissions associated with transportation would be higher than anticipated.

## 6.6 An alternative approach

The focus of this report has been on four different categories of light-duty vehicle that use a liquid fuel or electricity, or both. The different vehicles were compared in term of their availability, affordability, and acceptability. The state of Nova Scotia's economy, its ageing population, and its median family income suggest that the uptake of light-duty passenger electric-vehicles may be far slower than is needed to reduce Nova Scotia's greenhouse gas emissions and contribute to Canada's commitment to the Paris Agreement.

Although light-duty passenger vehicles are the single largest end-use source of greenhouse gas emissions in the province, there are other types of battery electric-vehicle which can help improve Nova Scotia's environmental acceptability, including commercial vans and passenger buses (for example, see (Nissan, n.d.; BYD, 2015)). Replacing existing commercial vans and passenger buses that use diesel as a fuel with their battery-electric equivalent can also reduce greenhouse gas emissions and offers other potential benefits, including reduced particulate matter, lower emissions of nitrogen oxides, and quieter streets.

Of particular interest to readers of this report is the battery-electric passenger bus. Like the light-duty electric-vehicles discussed in this report, the emissions associated with electric passenger-buses are less than their non-electric counterparts and the fuel costs are lower (Kane, 2013). Moreover, their size allows additional battery storage, increasing the time between charges (Field, 2015). At least one manufacturer has addressed the cold-weather operation issue by including a small liquid-biofuel heating system in the bus (New Flyer, n.d.). Battery-electric buses are also way to address some of the public's concerns regarding electric vehicles described in section 6.2; for example, riding an electric bus as well as seeing them in operation on the street would eventually become second nature.

By supporting electric passenger-buses, Nova Scotia Power and the province would not only raise the profile of electric vehicles, potentially encouraging their adoption, it would also be a way to reduce to reduce the risks associated with greenhouse gas emissions in the transportation sector. With a large enough fleet, battery-electric buses could justify the addition of more variable sources of renewable electricity on Nova Scotia Power's grid as the buses could smooth out periods of over or under production.

## **7 Concluding remarks**

Much of the economic expansion in developed western countries after the Second World War can be attributed to the growth in demand for the automobile. A key contributor to this growth has been the availability of low-cost liquid fuels. However, this growth has not been without its challenges: health and safety issues, environmental concerns, and fuel supply and price volatility have all contributed to changes in the design of the automobile. Despite this, two fundamental components of the automobile have remained unchanged for more than a century: the energy source is still a liquid fuel and the conversion process is still the internal combustion engine. Over the past 20 years, some automobile manufacturers have developed vehicles that rely on electricity for propulsion, thereby reducing the need for liquid fuel (the hybrid-electric vehicle) or eliminating it altogether (the battery-electric vehicle).

This report has examined some of the issues relating to the adoption of electric vehicles in a jurisdiction using a set of energy-security indicators, notably the availability of energy for the vehicle to meet the driver's transportation requirements, the affordability of the fuel (i.e., electricity) and the vehicle, and the acceptability of the emissions associated with driving the vehicle. In addition, the report has also considered related issues, such as subsidies, challenges to the uptake of electric vehicles, and road pricing.

The indicators were applied to electric vehicles in general terms and, when possible, applied to Nova Scotia. From this the report discussed:

**Availability.** The availability of the vehicle's energy source (a liquid fuel or electricity) is clearly essential to the vehicle's operation. In developed jurisdictions, the availability of electricity is not considered a risk. Since most BEVs are designed for distances of about 100km, they are often used for commuting, thereby allowing the driver to charge at home, or in some cases, both at home and work. The effect of cold temperatures on BEV range is well known, requiring additional charging for both auxiliary heating and to offset a decline in battery efficiency; using a CV during the winter months could reduce or even defeat the environmental benefits associated with BEVs.

In terms of Nova Scotia, it was shown that at present, Nova Scotia Power should have little difficulty in meeting the electricity demands of the limited number of BEVs in the province. However, if widespread adoption of BEVs was anticipated in a particular area of the province, there should be extensive three-phase load flow, voltage unbalance, and transformer loading studies conducted on the appropriate sections of the distribution grid to assess the overall potential impact of the infrastructure on the regional grid. If the number of BEVs were to increase substantially, it would be necessary for Nova Scotia Power to upgrade sections of the province's grid, to institute coordinated charging controlled by a smart grid and offering customers time-of-use or real-time billing.

Nova Scotia's winter weather could be expected to increase the number of charges required by longer-distance commuters, increasing their commuting time (if charging is during the commute is required) and adding to Nova Scotia Power's winter load.

**Affordability.** Affordability can be discussed on a number of levels. In terms of operating costs (i.e., energy cost per kilometre), BEVs can be considerably less expensive to drive than CVs; this is in part because of fuel taxes applied to liquid fuels but not electricity and, in some jurisdictions, BEVs can be charged at no cost. However, as electricity costs increase, the price differential is reduced as the efficiency of the CV improves. Energy costs notwithstanding, the most significant barrier to the widespread adoption of BEVs at present is their cost.

In Nova Scotia, the price of electricity (relative to the cost of a liquid fuel) makes driving a BEV less expensive than driving a CV (the difference could be expected to decline if the BEV was driven during the winter months); moreover, publically financed charging-stations do not require the driver to purchase the electricity, reducing the cost of driving it even further. However, when comparing the base price of a BEV and its home-charger with the average price paid by Nova Scotians for new vehicles, the annualized cost of the CV is less. This could be an issue in Nova Scotia, given the state of the provincial economy, its demographics, and average family income.

**Acceptability.** Perhaps the strongest argument for the purchase of a BEV is that, depending on the electricity supplier's energy mix, it can have lower per-kilometre emissions. The projected changes to Nova Scotia Power's generation mean that BEVs will become an increasingly better choice when it comes to emissions-per-kilometre than either HEVs or CVs.

At present, there are apparently very few BEVs or PHEVs in Nova Scotia. Given their price, it seems unlikely that they will become the vehicle-of-choice for most Nova Scotians for the foreseeable future; with the exception of the west coast of North America, this appears to be the

case in the United States as well. In light of this, subsidizing the installation of charging stations or the purchase of vehicles will benefit the very few Nova Scotians who are able to purchase such a vehicle.

If Nova Scotia Power (or its parent, Emera) wants to develop a network of publically accessible EVSEs (like PG&E in California) they should make a commitment to it, through the proper regulatory channels. Similarly, if Nova Scotia Power wants to increase the number of BEVs in the province, it should develop a plan to roll-out a smart grid with options for time-of-use or real-time pricing.

However, there are other ways in which transportation can be electrified in the province. One such approach is for the provincial government and Nova Scotia Power to support the introduction of battery-electric buses. This will help reduce transportation-related greenhouse gas emissions, lower the cost of operating public transportation, and importantly, raise the profile of battery-electric vehicles.

Ultimately, it is up to the provincial government to decide whether the province should develop a program encourage the uptake of battery-electric vehicles as part of a strategy to reduce the risks associated with the province's greenhouse gas emissions. However, rather than making it a one-off, ad hoc policy, it should be part of a new energy strategy that defines the province's energy future, not only targeting electrical generation and buildings, but the transportation sector as well.

## Appendix: Winter driving and range anxiety

As discussed in section 3.1, wintertime driving range can be reduced if the driver uses cabin heating. The following are some anecdotal examples of wintertime BEV driving experience:

- A Leaf owner in Minneapolis reported that though his vehicle had indicated a range of 50 miles (80 km) at -5°F (-20°C), after driving 19 miles (30 km) to work, the battery had depleted 9 of the 12 battery indicator-bars and indicated only 12 miles (19 km) range remaining. The vehicle then required a two-hour level-two charging session before returning home (Allen, 2013). Combining the 19 miles driven and the 12 miles remaining yields 31 miles (50 km) total range, considerably less than the 50 miles quoted at the beginning of the driver's commute.
- A Canadian consumer intending to replace the family vehicle with a BEV explained the experience in *The Globe and Mail*. The family tested three types of BEVs during the winter months: the 2015 Nissan Leaf, the Ford Focus, and the Mitsubishi i-MiEV. Notable in their experience were significant behavioural adaptations to meet charging requirements, specifically decreased in-cabin comfort due to the restriction of auxiliary services to maximize range, and charging challenges. With respect to in-cabin comfort, the author noted that driving home in the evening using auxiliary services like in-cabin heating, seat warming, radio and headlights consumed 53% of the total battery life. Further, after forgetting to plug-in the vehicle (an i-MiEV) while at the gym, the author recounted a stressful drive home where, by restricting all auxiliary services saw her reach the driveway with less than five kilometres to spare. Finally, as part of this exercise, various charging challenges were reported, particularly while charging at work. Other experiences noted included significant journey planning, limited availability of outlets, and nervousness on the part of building facilities management regarding the potential grid impacts of the vehicle (Nice, 2014).
- During a period of persistently cold temperatures in Illinois, EV drivers reported vehicles taking longer to charge and increased energy consumption rates. This resulted in adapted driver behaviour, including using only the seat-heater and heated steering wheel for warmth, to avoid the excessive battery consumption of the cabin heater (FleetCarma, 2014).
- Given that the Volt is a PHEV, the winter range restrictions are of less importance, as it merely results in increased gasoline consumption. However, for BEVs, like the Leaf, this reduced range could have significant impacts on the viability of a driver's commute, leading to increased range anxiety, as well as decreasing the relative comfort of that commute, resulting from intentional restriction of auxiliary power to maximize range.
- Additionally, in the comments section provided by FleetCarma on the topic, it was noted that in persistently cold climates, much more severe decreased range effects, with maximum ranges as low as 28 miles or 45 km quoted anecdotally by users, much lower than the stated vehicular range of 135 km (Allen, 2013).

## References

- Access Nova Scotia. (2015, April 30). *Fuel tax*. Retrieved May 23, 2015, from Access Nova Scotia: <http://novascotia.ca/sns/access/business/tax-commission/fuel-tax.asp#faq14256>
- AFDC. (2014, June 4). *Electric Vehicle (EV) Infrastructure and Battery Tax Exemptions*. Retrieved August 26, 2015, from U.S. Department of Energy - Alternative Fuels Data Center: <http://www.afdc.energy.gov/laws/6532>
- AFDC. (2015, January 2). *Benefits and Considerations of Electricity as a Vehicle Fuel*. Retrieved June 18, 2015, from Alternative Fuels Data Center, U.S. Department of Energy: [http://www.afdc.energy.gov/fuels/electricity\\_benefits.html](http://www.afdc.energy.gov/fuels/electricity_benefits.html)
- Agenbroad, J., & Holland, B. (2014, April 29). *Pulling Back the Veil on EV Charging Station Costs*. Retrieved June 3, 2015, from RMI Outlet: [http://blog.rmi.org/blog\\_2014\\_04\\_29\\_pulling\\_back\\_the\\_veil\\_on\\_ev\\_charging\\_station\\_costs](http://blog.rmi.org/blog_2014_04_29_pulling_back_the_veil_on_ev_charging_station_costs)
- Allen, M. (2013, December 16). *Electric Range for the Nissan Leaf & Chevrolet Volt in Cold Weather*. Retrieved April 2, 2015, from FleetCarma: <http://www.fleetcarma.com/nissan-leaf-chevrolet-volt-cold-weather-range-loss-electric-vehicle/>
- Allen, M. (2014, January 22). *Real-world range ramifications: heating and air conditioning*. Retrieved April 2, 2015, from FleetCarma: <http://www.fleetcarma.com/electric-vehicle-heating-chevrolet-volt-nissan-leaf/>
- Arcus, C. (2015, May 5). *Are Gasoline Prices Really Affecting EV Sales?* Retrieved January 3, 2016, from CleanTechnica: <http://cleantechnica.com/2015/05/05/are-gasoline-prices-really-affecting-ev-sales/>
- Berman, B. (2014a, October 24). *Buying Your First Home EV Charger*. Retrieved July 7, 2015, from PlugInCars: <http://www.plugincars.com/quick-guide-buying-your-first-home-ev-charger-126875.html>
- Berman, B. (2014b, July 16). *Electric Vehicle Charging Etiquette*. Retrieved July 7, 2015, from PlugInCars: <http://www.plugincars.com/eight-rules-electric-vehicle-etiquette-127513.html>
- Berman, B. (2014c, September 3). *The Real Price of EV Public Charging*. Retrieved July 7, 2015, from PlugInCars: <http://www.plugincars.com/guide-to-public-charging-costs.html>
- Bishop, T. H. (2008, June). *Unbalanced Voltages and Electric Motors*. Retrieved June 23, 2015, from Pumps & Systems: <http://www.pumpsandsystems.com/topics/motors/unbalanced-voltages-and-electric-motors-0>
- BMW. (2015a). *BMW i3*. Retrieved May 20, 2015, from BMW: [http://www.bmw.ca/ca/en/insights/special\\_offers/special\\_offers14.html](http://www.bmw.ca/ca/en/insights/special_offers/special_offers14.html)
- BMW. (2015b). *BMW i3 with Range Extender*. Retrieved May 20, 2015, from BMW: <http://mybmwi3.ca/>
- BMW. (n.d.). *Technical Data*. Retrieved July 7, 2015, from BMW i3: [http://www.bmw.com/com/en/newvehicles/i/i3/2013/showroom/technical\\_data.html](http://www.bmw.com/com/en/newvehicles/i/i3/2013/showroom/technical_data.html)

- Bohn, T. (2013, January 31). *PEV Charging Standards Status Including AC, DC and Wireless Technologies*. Retrieved June 30, 2015, from SAE International: [http://www.sae.org/events/gim/presentations/2013/pev\\_charging\\_standards\\_status.pdf](http://www.sae.org/events/gim/presentations/2013/pev_charging_standards_status.pdf)
- Botsford, C. (2015, July 13). *The Cal Electric Residential EVSE Program*. Retrieved July 23, 2015, from Energy Central: [http://www.energycentral.com/enduse/electricvehicles/articles/3203/?utm\\_source=2015\\_07\\_21&utm\\_medium=eNL&utm\\_content=217854&utm\\_campaign=PULSE\\_WEEKLY](http://www.energycentral.com/enduse/electricvehicles/articles/3203/?utm_source=2015_07_21&utm_medium=eNL&utm_content=217854&utm_campaign=PULSE_WEEKLY)
- Built By Michigan. (2015). *Electric Vehicles Are Paying Their Way*. Retrieved June 18, 2015, from Built by Michigan: <http://www.builtbymichigan.org/electric-vehicles-are-paying-their-way>
- BYD. (2015). *BYD - Build Your Dreams*. Retrieved January 4, 2016, from <http://www.byd.com/la/auto/ebus.html>
- Calvi, L. (2015, April 30). Don't forget to plug it in! *Chronicle-Herald - Wheels - Lady Drive*.
- Campbell, F. (2015, May 20). New Glasgow takes charge of conservation. *The Chronicle-Herald*.
- Canada. (2013, June 21). *Fuel Combustion - Refined Petroleum Products*. Retrieved January 11, 2016, from Environment Canada (Environment and Climate Change Canada): <https://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=AC2B7641-1#section2>
- Canada. (2015a). *National Inventory Report 1990-2013 - Greenhouse Gas Sources and Sinks in Canada - Part 3*. Gatineau, QC: Environment Canada.
- Canada. (2015b, February 11). *Canadian Climate Normals 1981-2010 Station Data*. Retrieved May 23, 2015, from Government of Canada - Climate Normals and Average: [http://climate.weather.gc.ca/climate\\_normals/results\\_1981\\_2010\\_e.html?stnID=6358&lang=e&StationName=halifax&SearchType=Contains&stnNameSubmit=go&dCode=1](http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?stnID=6358&lang=e&StationName=halifax&SearchType=Contains&stnNameSubmit=go&dCode=1)
- Canada. (2015c, February 11). *Hourly Data Report for Halifax Stanfield International Airport*. Retrieved May 20, 2015, from Government of Canada - Climate data: [http://climate.weather.gc.ca/climateData/hourlydata\\_e.html?timeframe=1&Prov=NS&StationID=50620](http://climate.weather.gc.ca/climateData/hourlydata_e.html?timeframe=1&Prov=NS&StationID=50620)
- CBC. (2015, September 1). *Gas shortages to continue in Nova Scotia if supply management not fixed*. Retrieved January 8, 2016, from CBC News Nova Scotia: <http://www.cbc.ca/news/canada/nova-scotia/gas-nova-scotia-shortages-analyst-1.3210993>
- CBC. (2015, September 29). *Muskrat Falls another 10% over budget, cost climbs to \$7.65B*. Retrieved December 29, 2015, from CBC News - Newfoundland and Labrador: <http://www.cbc.ca/news/canada/newfoundland-labrador/muskrat-falls-oversight-costs-1.3248460>
- Center for Sustainable Energy. (2015). *Clean Vehicle Rebate Project*. Retrieved June 18, 2015, from Center for Sustainable Energy: [https://energycenter.org/programs/clean\\_vehicle\\_rebate\\_project](https://energycenter.org/programs/clean_vehicle_rebate_project)
- Chargepoint. (2015). *FAQ: How much will I pay to charge my car?* Retrieved August 26, 2015, from Chargepoint: <http://www.chargepoint.com/faq/>

- Cole, J. (2015, February). *PG&E Looks To Quadruple California's EV Charging Stations. Cost? \$654 Million*. Retrieved August 26, 2015, from Inside EVs: <http://insideevs.com/pg-e-looks-quadruple-californias-public-charging-stations/>
- Davies, A. (2015, January 22). *BMW and VW team up to make EV charger networks anyone can use*. Retrieved July 23, 2015, from Wired: <http://www.wired.com/2015/01/bmw-vw-chargepoint/>
- Deloitte. (2011). *Unplugged: Electric vehicle realities versus consumer expectations*. Deloitte Touche Tohmatsu Limited - Global Manufacturing Industry group.
- Distance Canada. (n.d.). Retrieved May 25, 2015, from Distance Canada (distance calculator): <http://www.distancecanada.com/>
- EERE. (2011, February). *One Million Electric Vehicles By 2015 - February 2011 Status Report*. Retrieved June 18, 2015, from Office of Energy Efficiency and Renewable Energy: [https://www1.eere.energy.gov/vehiclesandfuels/pdfs/1\\_million\\_electric\\_vehicles\\_rpt.pdf](https://www1.eere.energy.gov/vehiclesandfuels/pdfs/1_million_electric_vehicles_rpt.pdf)
- EIA. (2014, December 10). *California leads the nation in the adoption of electric vehicles*. Retrieved August 26, 2015, from Energy Information Administration: <http://www.eia.gov/todayinenergy/detail.cfm?id=19131>
- EIA. (2015). *Light-Duty Vehicle Stock by Technology Type*. Retrieved June 23, 2015, from Annual Energy Outlook 2015 - Energy Information Administration: <http://www.eia.gov/beta/aeo/#/?id=49-AEO2015&cases=ref2015>
- Field, K. (2015, October 21). *A Look Under The Hood At The BYD Electric Bus Factory*. Retrieved January 4, 2016, from Cleantechnica: <http://cleantechnica.com/2015/10/21/look-hood-byd-electric-bus-factory/>
- Finance. (2010, August 1). *Finance Act - Chapter 2 of the Acts of 2010*. Retrieved from Nova Scotia Legislature: <http://nslegislature.ca/legc/statutes/finance.htm>
- Finance and Treasury Board. (2015, January 5). *Tobacco & Fuel*. Retrieved May 23, 2015, from Nova Scotia Finance and Treasury Board: <http://www.novascotia.ca/finance/en/home/taxation/tax101/tobaccofuel.aspx>
- FleetCarma. (2014). *How do extremely cold temperatures affect the range of an electric car?* Retrieved from FleetCarma: <http://www.fleetcarma.com/electric-car-range-in-bitter-cold/>
- GIWG. (2015). *2015 ZEV Action Plan - An updated Roadmap toward 1.5 Million Zero-Emission Vehicles - DRAFT*. Governor's Interagency Working Group on Zero-Emission Vehicles. Retrieved August 26, 2015, from [http://gov.ca.gov/docs/DRAFT\\_2015\\_ZEV\\_Action\\_Plan\\_042415.pdf](http://gov.ca.gov/docs/DRAFT_2015_ZEV_Action_Plan_042415.pdf)
- Gong, Q., Midlam-Mohler, S., Marano, V., & Rizzoni, G. (2012, March). Study of PEV charging on residential distribution transformer life. *IEEE Transactions on Smart Grid*, 3(1).
- Gourville, J. T. (2005, May). Note on Innovation Diffusion: Roger's Five Factors. *Harvard Business Review*, p. 6. Retrieved from <http://www.hbs.edu/faculty/Pages/item.aspx?num=32314>

- Hartman, K. (2015, March 12). *State Efforts Promote Hybrid and Electric Vehicles*. Retrieved June 18, 2015, from National Conference of State Legislatures: <http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx>
- Hughes, L. (2009, June). The four 'R's of energy security. *Energy Policy*, 37(6), pp. 2459-2461. doi: doi:10.1016/j.enpol.2009.02.038
- Hughes, L. (2012, January). A generic framework for the description and analysis of energy security in an energy system. *Energy Policy*, 42, pp. 221-231. doi:10.1016/j.enpol.2011.11.079
- Hughes, L., & Ranjan, A. (2013). Event-related stresses in energy systems and their effects on energy security. *Energy*, 59, pp. 413-421. doi:10.1016/j.energy.2013.06.070
- Hughes, L., & Sundaram, S. (2011). *Do Electric Vehicles Make Carbon-Sense in Nova Scotia? A Well-to-Wheels Analysis Using Nova Scotia Power's Electricity-Fuel Mix*. Halifax: (Funded by Nova Scotia Power).
- Hydro Quebec. (2015). *Power Quality*. Retrieved June 23, 2015, from Hydro Quebec - Customer Services: <http://www.hydroquebec.com/business/customer-services/power-quality/>
- IEA. (2014). *World Energy Outlook 2014*. Paris: International Energy Agency.
- IEA. (2015, December 11). *Highlights - World Oil Demand*. Retrieved January 8, 2016, from International Energy Agency - Oil Market Report: <https://www.iea.org/oilmarketreport/omrpublic/>
- Infrastructure Canada. (2013, November 14). *Infrastructure Spotlight: The Federal Gas Tax Fund*. Retrieved May 26, 2015, from Infrastructure Canada: <http://www.infrastructure.gc.ca/pub/infra/gtf-fte/gtf-fte-2013-eng.html>
- Infrastructure Canada. (2014, October 21). *The Federal Gas Tax Fund: Permanent and predictable funding for municipalities*. Retrieved from Infrastructure Canada: <http://www.infrastructure.gc.ca/plan/gtf-fte-eng.html>
- Johnson, P. M. (2005). *Free rider*. Retrieved Janaru 7, 2016, from A Glossary of Political Economy Terms: [https://www.auburn.edu/~johnspm/gloss/free\\_rider](https://www.auburn.edu/~johnspm/gloss/free_rider)
- Kane, M. (2013). *BYD Electric Bus Test Results in Canada*. Retrieved January 4, 2016, from InsideEvs: <http://insideevs.com/byd-electric-bus-test-results-in-canada/>
- Kopperson, B. R., Kubursi, A., Livingstone, A. J., Nadeem, A., & Slykhuis, J. (2014). *The Economic Impact of Electric Vehicle Adoption in Ontario*. Windfall Ecological Center. Retrieved June 18, 2015, from <http://www.windfallcentre.ca/drive-electric/docs/studies/GT80-EVAdoptionStudy-FullReport.pdf>
- Kress, R. (2015, September 3). *Despite Sales Lags, Electric Vehicles Setting New Standards for Performance and Quality*. Retrieved January 3, 2016, from The Fuse: <http://www.energyfuse.org/despite-sales-lags-electric-vehicles-setting-new-standards-for-performance-and-quality/>
- Leemput, N., Van-Roy, F. G., Olivella-Rosell, P., Driesen, J., & Sumper, A. (2015). MV and LV Residential Grid Impact of Combined Slow and Fast Charging of Electric Vehicles. *Energies*, 8, pp. 1760-1783. doi:10.3390/en8031760

- Lindsey, R. (2007). *Congestion Relief: Assessing the Case for Road Tolls in Canada*. Toronto: C.D. Howe Institute.
- Meyer, N., Whittal, I., Christenson, M., & Loiseau-Lapointe, A. (2012, May 6-9). The Impact of Driving Cycle and Climate on Electrical Consumption & Range of Fully Electric Passenger Vehicles. *EVS26 - International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium*. Retrieved May 15, 2015, from [http://www.tc.gc.ca/media/documents/programs/evs26\\_eng.pdf](http://www.tc.gc.ca/media/documents/programs/evs26_eng.pdf)
- Mitsubishi Motors. (2015). *Customize your 2015 Mirage*. Retrieved May 20, 2015, from Mitsubishi Motors: <http://www.mitsubishi-motors.ca/en/vehicles/mirage/2015/trims/es/builder/>
- Moritz, S., & Ohnsman, A. (2013, October 17). *Tesla Using AT&T Service in Cars*. Retrieved July 23, 2015, from Bloomberg: <http://www.bloomberg.com/news/articles/2013-10-17/tesla-will-use-at-t-service-in-cars>
- Moss, S. (2015, April 28). *End of the car age: how cities are outgrowing the automobile*. Retrieved April 30, 2015, from The Guardian - Cities - Cities in motion: <http://www.theguardian.com/cities/2015/apr/28/end-of-the-car-age-how-cities-outgrew-the-automobile>
- New Flyer. (n.d.). *Xcelsior Electric Bus*. Retrieved January 5, 2016, from New Flyer: <http://www.newflyer.com/index/electricbus>
- Newfoundland and Labrador. (2015, August). *Muskrat Falls Project Oversight Committee - Committee Report - August 2015*. Retrieved January 3, 2016, from Government of Newfoundland and Labrador - Muskrat Falls Oversight Committee: <http://www.gov.nl.ca/MFOversight/>
- Newman, P., & Kenworthy, J. (2011, June). 'Peak Car Use': Understanding the Demise of Automobile Dependence. *World Transport Policy and Practice*, 17(2), pp. 31-42. Retrieved June 22, 2015, from <http://www.eco-logica.co.uk/pdf/wtpp17.2.pdf>
- Nice, D. (2014, December 11). Why my family pulled the plug on owning and electric vehicle. *The Globe and Mail*. Retrieved April 2, 2015, from <http://www.theglobeandmail.com/globe-drive/culture/commuting/why-my-family-pulled-the-plug-on-owning-an-electric-vehicle/article22024557/>
- Nissan. (2015). *2015 Nissan Leaf*. Retrieved May 20, 2015, from Nissan: <http://www.nissan.ca/en/electric-cars/leaf/>
- Nissan. (n.d.). *Environmental Activities - CARWINGS*. Retrieved July 23, 2015, from Nissan Motor Corporation: <http://www.nissan-global.com/EN/ENVIRONMENT/SOCIAL/CARWINGS/>
- Nissan. (n.d.). *Get ready to to electric e-NV200*. Retrieved January 5, 2016, from Nissan: <http://www.env2000.com>
- Nova Scotia. (2009). *Official Inspection Station Manual - Passenger and Light Commercial Vehicles 4500 kg or less*. Halifax: Vehicle Administration Section.
- Nova Scotia. (n.d.). *Fossil fuels, including natural gas—a cleaner-burning fossil fuel— have a role to play in our energy future*. Retrieved January 8, 2016, from Nova Scotia Department of Energy (Oil and Gas): <http://energy.novascotia.ca/oil-and-gas>

- NRCan. (2014, September 15). *Government taxes on gasoline*. Retrieved May 23, 2015, from Natural Resources Canada: <https://www.nrcan.gc.ca/energy/fuel-prices/4939>
- NRCan. (2015a, March 9). *Fuel Consumption Ratings Search Tool*. Retrieved March 15, 2015, from Natural Resources Canada - Office of Energy Efficiency: <http://oee.nrcan.gc.ca/fcr-rcf/public/index-e.cfm>
- NRCan. (2015b, March 10). *Fuel Consumption Testing*. Retrieved from Natural Resources Canada: <http://www.nrcan.gc.ca/energy/efficiency/transportation/cars-light-trucks/buying/7491>
- NRCan. (2015c, February 5). *Transportation Sector Nova Scotia Table 10: Passenger Road Transportation Secondary Energy Use and GHG Emissions by Energy Source*. Retrieved May 22, 2015, from Natural Resources Canada - Office of Energy Efficiency - Comprehensive Energy Use Database: <http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=tran&juris=ns&rn=10&page=0>
- NRCan. (2015d, February 5). *Transportation Sector Nova Scotia Table 21: Car Explanatory Variables*. Retrieved March 12, 2015, from NRCan - Office of Energy Efficiency - Comprehensive Energy Use Database: <http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=tran&juris=ns&rn=21&page=0>
- NS DOE. (2013, August 25). *NS EV Highway Services*. Retrieved May 17, 2015, from Nova Scotia Department of Energy - NS Moves Grant Recipients: NS EV Highway Services
- ODOE. (n.d.). *Alternative Fuel Vehicle Fueling and Charging*. Retrieved August 26, 2015, from Oregon Department of Energy: Transportation: <http://www.oregon.gov/energy/TRANS/Pages/hybridcr.aspx>
- Onstar. (n.d.). *Onstar Services*. Retrieved July 23, 2015, from Onstar: <https://www.onstar.com/ca/en/services/services.html>
- Pesaran, A., Santhanagopalan, S., & Kim, G.-H. (2013, March 11-14). *Addressing the Impact of Temperature Extremes on Large Format Li-Ion Batteries for Vehicle Applications*. Retrieved May 17, 2015, from National Renewable Energy Laboratory: <http://www.nrel.gov/docs/fy13osti/58145.pdf>
- PG&E. (2015, February 9). *PG&E Proposes Major Build-Out of Electric Vehicle Charging Stations - News Release*. Retrieved July 23, 2015, from PG&E External Communications: [http://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20150209\\_pge\\_proposes\\_major\\_build-out\\_of\\_electric\\_vehicle\\_charging\\_stations](http://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20150209_pge_proposes_major_build-out_of_electric_vehicle_charging_stations)
- PG&E. (2013, November 27). *Schedule 344 - Oregon Electric Vehicle (EV) Highway Pilot Rider (PUC Oregon No. E-18)*. Retrieved August 26, 2015, from Portland General Electric Company: [https://www.portlandgeneral.com/our\\_company/corporate\\_info/regulatory\\_documents/pdfs/schedules/Sched\\_344.pdf](https://www.portlandgeneral.com/our_company/corporate_info/regulatory_documents/pdfs/schedules/Sched_344.pdf)
- PlugInCars. (2015). *Cars*. Retrieved February 24, 2015, from plugincars: <http://www.plugincars.com/cars>

- PSE. (2015). *Charging ahead with electric vehicles - Get a \$500 rebate on qualified Level 2 EV chargers*. Retrieved June 18, 2015, from Puget Sound Energy: <http://www.pse.com/savingsandenergycenter/AlternativeFuelVehicles/Pages/Electric-vehicles.aspx>
- Pushkarna, S. (2015, April 15). *Electric Vehicles in Nova Scotia: Current State and Planning for the Future*. *Smart Energy Event*. World Trade and Convention Centre, Halifax, Nova Scotia.
- Pyper, J. (2014, November 25). *Wisconsin Is the Latest State to Demand EVs and Hybrids Pay Their 'Fair Share' for Roads*. Retrieved June 18, 2015, from Greentech Media: <http://www.greentechmedia.com/articles/read/wisconsin-becomes-latest-to-propose-fee-on-evs-and-hybrids>
- REEV. (n.d.). *REEV*. Retrieved January 3, 2016, from The Free Dictionary: <http://acronyms.thefreedictionary.com/REEV>
- Rogers, E. (2003). *Diffusion of innovations* (5th ed.). New York: The Free Press.
- SCE. (2015a). *SCE Introduces a New Residential Time-Of-Use Rate Plan*. Retrieved August 26, 2015, from Southern California Edison: [https://www.sce.com/wps/portal/home/residential/rates/residential-plan!/ut/p/b1/rVXRcqlwFP2V9sHHyA1JCOwb7lortmqrdisvThIC0IG0yOq2X7\\_BdXaLtrXulhImcsm5B87JvRcrtO6tMBPrNBFFusjErlxDZ4Ldln\\_ZHkDbbZAmtBvQ6\\_q3PnQ4GMDYAOcNy4dqfms09E3-twa-vG4DdKn13QqtUGXFspa45XSE7X](https://www.sce.com/wps/portal/home/residential/rates/residential-plan!/ut/p/b1/rVXRcqlwFP2V9sHHyA1JCOwb7lortmqrdisvThIC0IG0yOq2X7_BdXaLtrXulhImcsm5B87JvRcrtO6tMBPrNBFFusjErlxDZ4Ldln_ZHkDbbZAmtBvQ6_q3PnQ4GMDYAOcNy4dqfms09E3-twa-vG4DdKn13QqtUGXFspa45XSE7X)
- SCE. (2015b). *Schedule TOU-EV-1 - Domestic Time-of-Use - Electric Vehicle Charging*. Retrieved August 26, 2015, from Southern California Edison: <https://www.sce.com/NR/sc3/tm2/pdf/ce114-12.pdf>
- Stantec. (2013, April). *Quantifying the Costs and Benefits to HRM, Residents and the Environment of Alternate Growth Scenarios*. Retrieved August 27, 2015, from Halifax Regional Municipality: <https://www.halifax.ca/boardscom/documents/HRMGrowthScenariosFinalReportApril292013.pdf>
- Statistics Canada. (2013). *2011 National Household Survey*. Ottawa: Statistics Canada.
- Statistics Canada. (2014a, April 17). *Focus on Geography Series, 2011 Census - Province of Nova Scotia*. Retrieved March 15, 2015, from Statistics Canada - Census - Analytical products - Focus on Geography Series: <http://www12.statcan.gc.ca/census-recensement/2011/as-sa/fogs-spg/Facts-pr-eng.cfm?Lang=Eng&GC=12>
- Statistics Canada. (2015a, June 26). *Median total income, by family type, by province and territory (All census families) - CANSIM table 111-0009*. Retrieved January 3, 2016, from Statistics Canada: <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/famil108a-eng.htm>
- Statistics Canada. (2015b). *Table 079-0003 - New motor vehicle sales, Canada, provinces and territories, monthly*. Ottawa: Statistics Canada. Retrieved May 24, 2015
- Statistics Canada. (2015c). *Table 405-0004 - Road motor vehicles, registrations, annual (number)*. Ottawa: Statistics Canada. Retrieved May 24, 2015

- Sullivan, H. (2015a, March 17). *County asked to pay for installation of electric vehicle charging stations at private business sites*. Retrieved April 6, 2015, from Truro Daily News: <http://www.trurodaily.com/News/Local/2015-03-17/article-4080511/County-asked-to-pay-for-installation-of-electric-vehicle-charging-stations-at-private-business-sites/1>
- Sullivan, H. (2015b, April 27). *Electric charging stations to be installed in some rural areas of Colchester County*. Retrieved July 22, 2015, from The Truro Daily News: <http://www.trurodaily.com/News/Local/2015-04-27/article-4126236/Electric-charging-stations-to-be-installed-in-some-rural-areas-of-Colchester-County/1>
- The Car Electric. (n.d.). *Electric Car Benefits By State*. Retrieved June 18, 2015, from The Car Electric: <http://www.thecarelectric.com/content/electric-car-benefits-by-state.php>
- The Daily. (2014, September 17). *Population projections: Canada, the provinces and territories, 2013 to 2063*. Retrieved February 26, 2015, from Statistics Canada: <http://www.statcan.gc.ca/daily-quotidien/140917/dq140917a-eng.htm>
- Toyota. (2015a). *2015 Prius*. Retrieved May 20, 2015, from Toyota: <http://www.toyota.ca/toyota/en/vehicles/prius/overview>
- Toyota. (2015b). *2015 Prius Plug-in Hybrid*. Retrieved May 20, 2015, from Toyota: <http://www.toyota.ca/toyota/en/vehicles/prius-plugin/overview>
- Tuan, T. Q., Le Pivert, X., Saheli, M., & Beaude, O. (2012). Stochastic approach to assess impacts of electric vehicles on the distribution network. *3rd IEEE PES International Conference and Exhibition on Innovative Smart Grid Technologies (ISGT Europe)* (pp. 1-8). Berlin: IEEE.
- Turrentine, T. S., Garas, D., Lentz, A., & Woodjack, J. (2011). *The UC Davis MINI E Consumer Study, University of California, Davis*. Institute of Transportation Studies.
- UNEP. (2015). *The Emissions Gap Report 2015*. Nairobi: United Nations Environment Programme.
- UNFCCC. (2015). *Paris Agreement (Annex)*. Paris: United Nations Framework Convention on Climate Change COP-21.
- VOCM News. (2015, March 3). *Question of the Day*. Retrieved April 3, 2015, from VOCM: <http://vocm.com/qotd.asp?archivedid=1479>
- VW. (2015, February 10). *Volkswagen of American to invest \$10 million in electric vehicle charging infrastructure by 2016*. Retrieved July 20, 2015, from Volkswagen of American: <http://media.vw.com/release/920/>
- WA DoC. (2012). *Electric Drive WA*. Retrieved June 18, 2015, from Washington State Department of Commerce: <http://www.commerce.wa.gov/Programs/Energy/electric-vehicles/Pages/default.aspx>
- WCGH. (2008, June 20). *Memorandum of Understanding on Alternative Fuel Distribution*. Retrieved August 26, 2015, from West Coast Green Highway: <http://www.westcoastgreenhighway.com/pdfs/BC-WAAAlternativeFuelMOU.pdf>
- WCGH. (2014). *West Coast Electric Highway*. Retrieved July 23, 2015, from West Coast Green Highway (Washington State Department of Transportation): <http://www.westcoastgreenhighway.com/electrichighway.htm>

Wolf, W. (1996). *Car Mania: A Critical History of Transport*. (G. Fagan, Trans.) London: Pluto Press.

World Bank. (2015). *Transport*. Retrieved May 23, 2015, from The World Bank:  
<http://www.worldbank.org/en/topic/transport>

Yuksel, T., & Michalek, J. J. (2015, February 15). Effects of Regional Temperature on Electric Vehicle Efficiency, Range, and Emissions in the United States. *Environmental Science and Technology*, pp. 3974–3980. doi:10.1021/es505621s