Medium and Heavy Duty Transportation Greenhouse Gas Emissions Reduction Guide for Local Governments

2019

FORTIS BC
Energy at work

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CONTENTS

About this guide

This is a practical guide for local governments and policy makers on commercial transportation market transformation. The guide covers technologies and policy options for local governments as well as key levers provincial and federal governments have to accelerate emissions reductions and transform commercial vehicle markets.

Acknowledgements

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FortisBC, a natural gas and electric distribution utility, supports natural gas and renewable natural gas vehicle and marine applications, and electric vehicles. FortisBC is a co-funder of the project, a member of the project steering committee, and a Community Energy Association member.

The Sitka Foundation supports environmental change makers who preserve biodiversity and protect the environment. The Sitka Foundation seeks out impactful investment opportunities, meaningful relationships with conservation experts, and creative collaboration opportunities involving many stakeholders that result in positive change for our environment in the Pacific Northwest. https://sitkafoundation.org/

Disclaimer

The views expressed herein do not necessarily represent the views of the funders.

About Community Energy Association

The Community Energy Association is a charitable organization that supports BC local governments with climate action in their community and own corporate operations. CEA helps to accelerate building energy efficiency, renewable energy projects and sustainable transportation through community energy planning and project implementation. To download a copy of this guide or additional resources for local governments, please visit: www.communityenergy.bc.ca.

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EXECUTIVE SUMMARY

This guide was developed to help small and large BC communities decarbonize commercial transportation by reducing greenhouse gas emissions from medium and heavy duty vehicles operating within the community and municipal fleets. The medium duty vehicle (MDV) classification includes all ¼ ton and five ton trucks (vehicle classes 4-6) while the heavy duty vehicle classification includes all tractor trailers and most transit buses (vehicle classes 7-8).

According to CEA's analysis of the 2010 Community Energy & Emissions Inventory produced by the Province of BC, transportation as a whole accounts for 39% of BC's emissions, with commercial transportation accounting for approximately 31% of BC's total transportation emissions. The estimated fuel purchase costs associated with these emissions is **$2.2 billion per year**. [1]

Decarbonizing medium and heavy-duty transportation requires improving on at least one of four measures (Figure E1):

1. Route & load optimization
2. Driver efficiency
3. Vehicle efficiency
4. Fuel switching to low carbon fuels

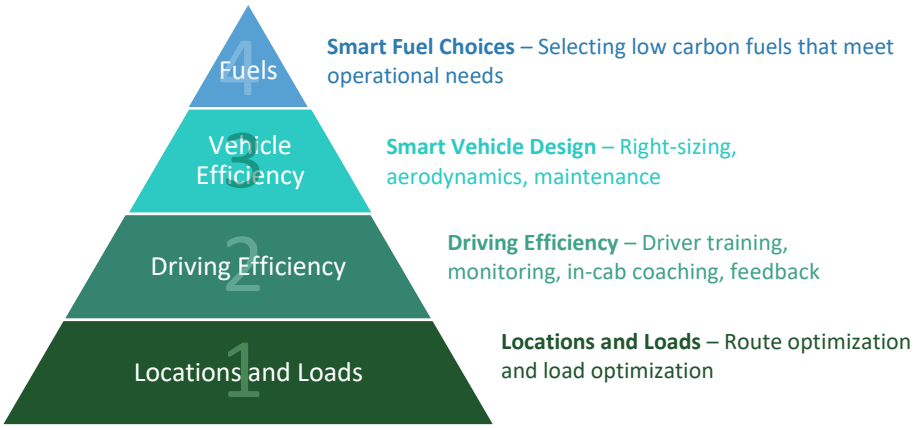


Figure E1: Approaches to Commercial Transportation Decarbonization

This guide focuses primarily on Step 4 – switching to low carbon fuels. Information on vehicle and driver efficiency is included in Appendix C. Route & load optimization is considered within the Local Government Action section.

Fuel switching can be achieved through using lower carbon fuels suited for existing gasoline or diesel based MDVs and HDVs, or by changing or converting vehicle technologies so that other lower carbon fuels such as natural gas, renewable natural gas, hydrogen or electricity can be used. Local governments can directly decarbonize their corporate transportation portfolio by purchasing alternatively fuelled vehicles for their fleet. Vancouver, Surrey, Kamloops, Montreal, and Ottawa are all examples of cities that have converted sections of their fleet (e.g. refuse trucks or city buses) from diesel to either electric, hybrid, or compressed natural gas (CNG), liquefied natural gas (LNG) or renewable natural gas (RNG).

Overall, local governments can employ five approaches to drive decarbonization in medium and heavy duty **municipal fleets** and **within private sector fleets** operating within their community:

Lead: Optimize local government fleet operations through efficiency measures and switch to low or no carbon fuels.

Enable: Consider locations for alternative fuel refueling facilities and provide policy support.

Invest & Save: Seek opportunities to invest in cost-effective fuel solutions.

Manage: Explore transportation demand management approaches appropriate for medium and heavy duty fleets.

Promote & Inform: Be aware of and promote innovative approaches being implemented in private fleets.

[1] Emission numbers were derived from the Province of BC's Community Energy & Emissions Inventory for the year 2010 for medium duty trucks, heavy duty trucks, commercial vehicles, and tractor trailer trucks. Associated costs for the same year were derived from Statistics Canada.

BC local governments can also access a range of funding sources for alternative fuelled vehicles, including FortisBC, the Province of BC, Federation of Canadian Municipalities, and the federal Gas Tax Fund.

Local governments looking to pursue their own corporate fleet decarbonization should consult the task list provided in Table 5. Local governments can also use policies and capital to stimulate change within the private sector by:

- investing in the development of biodiesel and renewable natural gas,
- constructing alternative fuel stations,
- optimizing transportation routes by restricting MDV and HDV traffic to specific urban routes to mitigate congestion,
- updating commercial licensing systems and procurement policies to favour alternative fuelled vehicles, and
- providing efficient driver education.

The right fuel switching choice for a specific vehicle will depend on how the vehicle is used as well as the relative prioritization of cost, emissions savings, risk tolerance, and local repair and maintenance capacity.

OVERVIEW OF COMMERCIAL TRANSPORTATION IN BC

DEFINING MEDIUM AND HEAVY DUTY VEHICLES

In Canada, commercial trucks are classified based their on gross vehicle weight rating (GVWR). Medium duty trucks range from Class 4 through 6, while heavy-duty trucks range from Class 7-8. Both classes of vehicles are summarized in Table 1.

Table 1: Commercial Truck Classifications

Class of truck	Characteristics of movement	GVWR
Medium duty (Class 4-6)	Includes all ¼ ton to 5 ton trucks (e.g. Box truck, semi-trailer truck)	14,001 – 26,000 lb
Heavy duty (Class 7-8)	Includes all tractor trailers, most transit buses, requires commercial driver's license to operate	26,000+ lb

MEDIUM-DUTY COMMERCIAL VEHICLES

Medium duty commercial vehicles (MDVs) include any vehicles in Classes 4 through 6, with a gross vehicle weight rating (GVWR) of 14,001 – 26,000 lb.

As of 2016, there were 117,700 MDVs registered in BC, comprised of approximately 70,900 diesel and 44,900 gasoline vehicles. Average annual fuel consumption for each fuel type was around 5,800 L per diesel MDV and 5,100 L per gasoline MDV.[2]

Medium duty vehicles include the following vehicle types:

- Large walk-in trucks
- Box trucks
- Delivery trucks
- Bucket trucks
- Small school buses
- Beverage trucks
- Refrigeration

Medium duty commercial vehicles used for short-haul delivery of goods and services, including:

- Furniture moving
- Couriers
- Lighter waste trucks
- Fire trucks
- Public service trucks
- Construction
- Landscaping
- Emergency services
- Refrigerated transport
- Flatbed towing

[2] This estimate is based on 2012 CEEI data for transportation, and prorated for increases in population to 2016.

HEAVY DUTY COMMERCIAL VEHICLES

Heavy-duty commercials vehicles (HDVs) include Class 7 or 8, with a GVWR of >26,000 lb. As of 2016, there were 81,500 heavy duty vehicles in BC – 36,700 heavy duty trucks, 10,100 buses, and 34,700 tractor trailers.[3]

Heavy duty vehicles include the following vehicle types:

- Tractor-trailers
- Logging trucks
- City transit buses
- Garbage trucks
- Cement mixers
- Mobile cranes

Heavy duty commercial vehicles are primarily used to transport all sorts of heavy and bulky cargo. Transit buses also fall into the HDV category. Industries that use HDVs include:

- Agriculture
- Drayage
- Forestry
- Construction
- Solid waste disposal Liquid waste disposal
- Freight delivery
- Public transportation

GREENHOUSE GAS EMISSIONS

Transportation is a primary source of GHG emissions in BC, contributing 25 megatonnes (Mt) CO_2e to the atmosphere in 2016. Transportation emissions represent 39% of BC's total GHG emissions. Of total transportation emissions, 31% originates from commercial vehicles.[i]

Reducing B.C. Transportation Emissions

Transportation accounts for 39% of B.C.'s greenhouse gas emissions, or 25 million tonnes per year of carbon pollution. B.C. is committed to reducing GHG emissions steadily, over the next few decades.

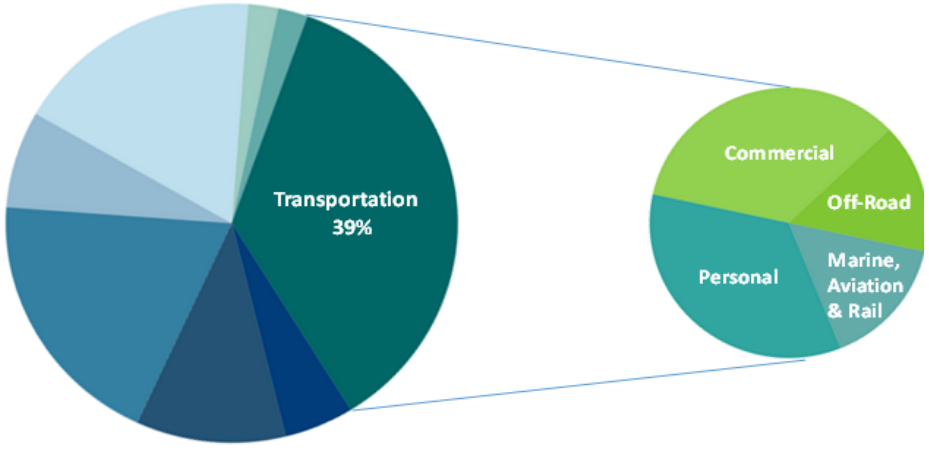


Figure 1: ***Clean Transportation: Building a clean growth future for B.C*** **(Intentions Paper, Province of B.C., 2018)**

[3] Based on 2012 CEEI data, projected based on population increases to 2016

Emissions from transportation typically account for 20 - 45% of municipal operational emissions, according to a Community Energy Association analysis of Climate Action Revenue Incentive Program Reports. Almost all (187 of 190) of BC local governments have signed onto the Climate Action Charter, which requires communities to become carbon neutral in their corporate operational emissions, while also reducing community-wide emissions.

AIR QUALITY IMPACTS

According to Environment and Climate Change Canada, in 2017, transportation, off-road vehicles and mobile equipment accounted for more than half of total national emissions of carbon monoxide (CO) and nitrogen oxides (NOX). These applications also accounted for 16% of total emissions of volatile organic compounds (VOCs).[ii]

Diesel fuel in particular is a significant source of particulate emissions such as PM2.5, or fine particulate matter, which causes respiratory issues, especially in urban centres. Particulate matter is on the Canadian Environmental Protection Act's list of toxic substances. Metro Vancouver estimated that health impact costs of PM2.5 in in the region at $813/tonne.[iii] For example, a switch from diesel fuel to natural gas for on-road transportation essentially eliminates NOx, SOx and particulate matter, which has direct and immediate impacts to local air quality in the regions in which these vehicles operate.

LOCAL GOVERNMENT ROLE IN REDUCING EMISSIONS

Local governments can employ five approaches to drive decarbonization in medium and heavy duty **municipal fleets** and **within private sector fleets** operating within their community:

Lead: Optimize local government fleet operations through efficiency measures and switch to low or no carbon fuels.

Enable: Consider locations for alternative fuel refueling facilities and provide policy support.

Invest & Save: Seek opportunities to support new fuels.

Manage: Explore transportation demand management approaches appropriate for medium and heavy duty fleets.

Promote & Inform: Be aware of and promote innovative approaches being implemented in private fleets.

FUEL & TECHNOLOGY ALTERNATIVES

According to the Province of BC's Renewable and Low Carbon Fuel Requirements Regulation Summary: 2010 – 2017, the following "emissions avoided" and default carbon intensities for a given compliance period have been calculated for a set of available alternative fuels. Carbon intensity is the measure of greenhouse gas (GHG) emissions associated with producing and consuming a transportation fuel, measured in grams of carbon dioxide equivalent per mega joule of energy (gCO2e/MJ). Carbon intensity accounts for the GHG emissions associated with extracting, producing, transporting, and consuming a unit of energy of transportation fuel. It is a measure of the GHG emissions from the complete life cycle assessment (LCA) of a fuel.

Carbon intensity for regular gasoline and diesel fuel are 88.14 and 94.76 gCO2e/MJ respectively.[4] Table 2 lists lifecycle emissions avoided and annual weighted average carbon intensity for eight alternative transportation fuels available in BC.

Table 2: Approved Carbon Intensities for Alternative Fuels under the Low Carbon Fuel Regulation

Fuel	Lifecycle Emissions Avoided (tonnes CO_2e) 2017	Annual Weighted Average Carbon Intensity (gCO_2e/MJ) in 2017
Biodiesel	335,198	6.49
Compressed Natural Gas (CNG)	17,923	63.64
Electricity	165,981	19.73
Ethanol	493,529	32.48
Hydrogen	20	96.82
Liquid Natural Gas (LNG)	20,168	63.08
Propane	35,062	67.97
Renewable Natural Gas (RNG)	Not available	*7.33 – 30.80
Additional Breakdown of Carbon Intensities by Hydrogen Production Method		
Hydrogen via Electrolysis		4.23
Hydrogen via Natural Gas Reforming		71.4
Hydrogen via Natural Gas Reforming (w/ Carbon Capture & Storage)		14.3

* Not reported in the annual average weight table. Range is as reported for fuels BCLCF263 – 266 via the 2019 Approved Carbon Intensities Information Bulletin RLCF-012.

Renewable natural gas (RNG) is derived from biogas, which is produced from decomposing organic waste from landfills, agricultural waste and wastewater from treatment facilities. The biogas is captured and cleaned to create lower carbon renewable natural gas. RNG is interchangeable with conventional natural gas, which is an added advantage for existing natural gas customers in that no modifications are required to vehicles or equipment to consume RNG in place of conventional natural gas. RNG is considered a substitute for CNG, and is reliant on CNG refueling infrastructure.

Additionally, RNG users earn credits under B.C.'s Low Carbon Fuel Requirements Regulation and based on the current approved carbon intensities under this Regulation (shown in Table 2), RNG credits earn additional credits over those earned from using CNG. As a result, net RNG fuel costs are comparable to CNG after the monetization of these low carbon fuel credits.

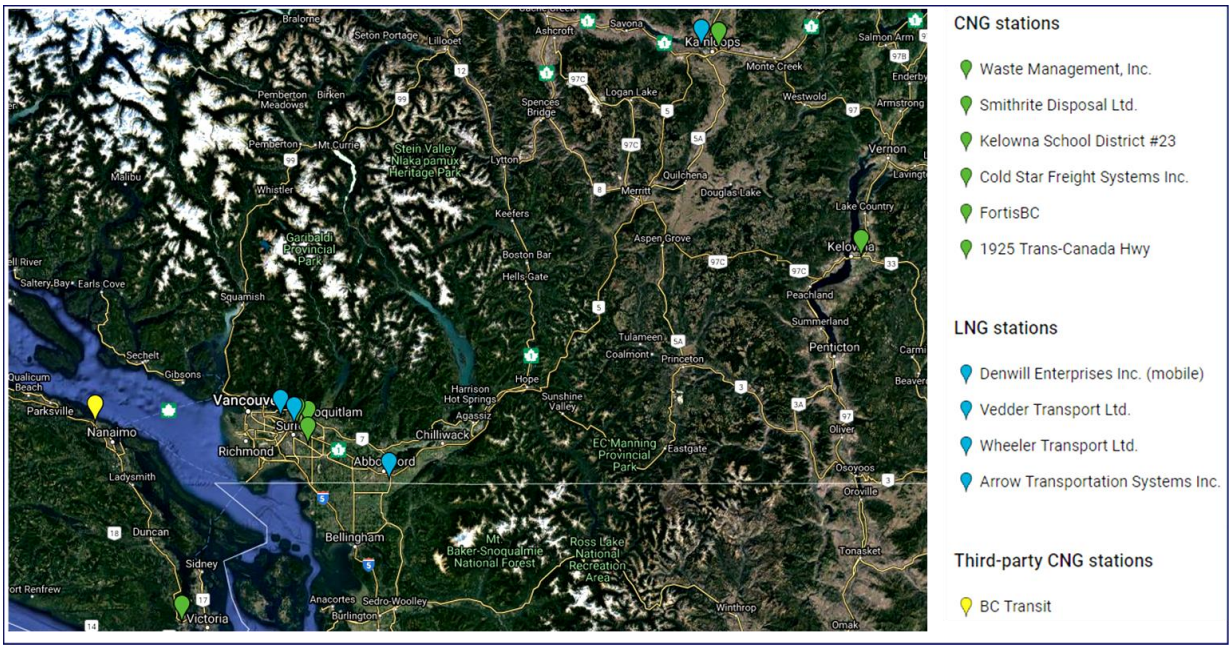
Worldwide, the medium- and heavy-duty truck market is projected to continue its reliance on conventional diesel fuel for the next decade. However, alternative fuel refueling opportunities are available to MDV and HDV vehicles in BC. Compressed natural gas (CNG), liquefied natural gas (LNG) and renewable natural gas (RNG) refueling opportunities are

[4] Extracted from *Carbon Intensity Records* under the *Renewable and Low Carbon Fuel Requirements Regulation* (Source: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/transportation/renewable-low-carbon-fuels/rlcf006_-_carbon_intensity_records.pdf (April 2019)

available today in large and medium sized communities. Biodiesel and ethanol fueling opportunities are currently restricted to larger urban centres. (Figure 3.)

British Columbia has been a leading developer and test bed for fuel cell products for both the transportation and stationary power markets. The provincial government has expressed support for investments in education, research, demonstration projects and fuel station implementation. In 2018, there were two public hydrogen fueling station operating in the province – one at Powertech Labs in Surrey (a wholly owned subsidiary of BC Hydro), and another in Vancouver. The latter station is operated by Shell and Hydrogen Technology & Energy Corporation (HTEC), which is building a six-station network in Greater Vancouver and Victoria. Shell is collaborating with HTEC on three additional stations. The Hydrogen Fueling Infrastructure Program is managed by the Canadian Hydrogen & Fuel Cell Association. Expansion of the hydrogen fueling network in British Columbia is anticipated to begin to reduce barriers to hydrogen vehicle market adoption.

Figure 3: Map of CNG and LNG Stations in BC (Fortis BC, 2019)



A 2017 report from Navigant market research examined the global market for medium- and heavy-duty trucks across hybrid, electric, and fuel-cell powertrains and projected annual sales and vehicle numbers to 2027. Hybrid and electric powertrains numbers are expected to increase worldwide from about 125,500 to 1.66 million from 2017 to 2027. This projection suggests that the market is accelerating for these kinds of powertrains.[iv] However, hybrid and electric MDV and HDV powertrains are not yet commercially viable in BC.

In Canada, Loblaws has committed to having a fully electric fleet by 2030 and has pre-ordered 10 electric HDVs.[v] While originally scheduled for 2019 delivery, production of the vehicles is delayed and actual delivery dates are undetermined. [vi]

The following alternative fuels for MDVs and HDVs are commercially ready in BC today: CNG[vii], RNG[viii], LNG[ix], biodiesel[x], and hybrid electric[xi]. Electricity as an MDV/HDV fuel [xii] is expected to be technically available within the next 5-10 years, but commercialization will depend on proven performance and a reduction in cost premiums. Long haul hydrogen trucks are in the testing phase. Both the cost of fuel and price of the vehicles remain significantly higher than conventional trucks.

Figure 4 places each of the alternative fuels on a cost and availability continuum. The size of the dot represents an estimate of the relative GHG savings achievable with each of the fuels.

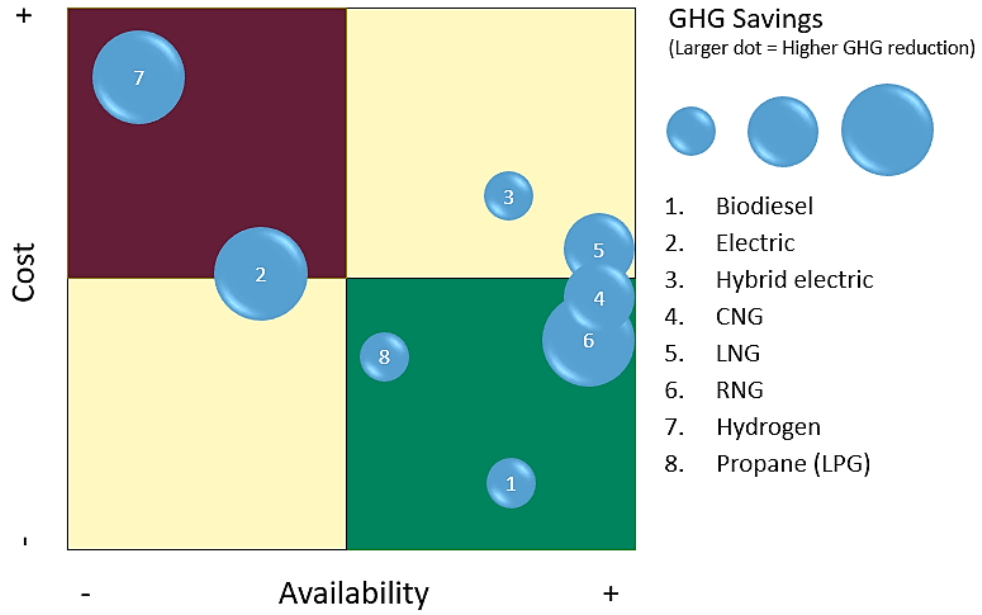


Figure 4: Relative Cost and Availability of Alternative Fuels (Source: Community Energy Association, 2019)

MEDIUM DUTY VEHICLES

Daily distance requirements, load amounts, number of start/stop cycles, and stationary energy requirements all factor into choosing the appropriate fuel for the necessary task. Where, how, and frequency of usage will ultimately all affect the environmental and financial bottom lines. For example:

Daily distance requirements, load amounts, number of start/stop cycles, and stationary energy requirements all factor into choosing an appropriate fuel for the necessary task.

- Delivery trucks typically operate within urban centres, with a high number of start/stop cycles due to multiple deliveries.
- Refrigeration trucks often travel moderate distances whether in urban or rural settings. In addition, their contents must be consistently kept cold, leading to high stationary and mobile energy use.
- Fire trucks often travel moderate to long distances and must do so quickly for emergencies, with minimal start/stop cycles, and with stationary power requirements at emergency scenes.

General scaling considerations

- Vehicle range
- Expected duty cycles
- Increasing efficiencies to decrease truck size
- Time effects of recharging /refilling
- Ability of initiative to meet your GHG emission goals

Urban or Rural?

- Urban users can apply MDVs to a wide range of applications and have more flexiblity in dedicating or multi-purposing trucks
- Rural users have to be more critical when choosing a truck; they may need to multi purpose a vehicle to merit feasibilty.

MDVs have a small role in the larger goods distribution supply chain, typically being used for the "last kilometre."[xiii] However, 40% of MDV usage is for non-goods distribution purposes (e.g. public service vehicles), providing a significant opportunity for municipal governments to reduce emissions through vehicle purchasing agreements. Choosing an appropriate fuel depends on assessing four application-specific criteria:

- daily distance travelled,
- load requirements,
- frequency of start/stop cycles, and
- stationary energy needs.

CNG/RNG technology and fuels can be suitable for all MDV applications. CNG/RNG vehicles with original equipment manufacturer (OEM) engines having been available for over 8 years[xiv]. At present, new vehicle purchases are not required for CNG/RNG vehicles – existing vehicles can be converted with using a conversion kit. In dual-fuel vehicles, CNG and LPG vehicles are subject to cold starting issues; gasoline or diesel is often used during ignition before switching to CNG. LNG is not suitable for most MDV applications, because the typical low mileage of MDVs results in significant evaporative losses while vehicles are not in use. LNG is more suited for long haul HDVs that use large quantities of fuel in shorter periods.

Many MDV applications are based on short-distance, intercity routes, with many start-stop cycles, cold starts and brake wear. The shorter distances mean MDVs often need to carry less energy onboard than heavy-duty (class 7 and 8) or long-haul vehicles. This is important when considering electric and hybrid electric drive options, because modern lithium-ion battery banks need to be 6-10 times the volume of a diesel tank to travel the same distance, which will significantly reduce the volume available for payload. Electric and hybrid electric MDVs also carry a cost premium. Acceptance of electric alternatives is increasing but implementation is slow because of a lack of experience in the market and increased costs.

As for new purchases, diesel electric and electric technologies are promising, though still in the demonstration phase, and the range of electric trucks is low. When looking at combined capital and lifetime cost today, CNG/RNG options are best for both trucks and buses, with hybrid electric, and electric providing potential options as well. Again, hydrogen does not reach financial parity when compared to diesel.

MDV motors in electric and diesel electric hybrids mitigate issues of idling and brake wear by taking advantage of regenerative braking. They are also less prone to efficiency issues with start-stop cycles, although extreme weather situations will require the batteries to be kept warm when off to reduce efficiency losses. Electric motors however, are hindered by the energy density of modern lithium-ion batteries. Even though electric motors are 3-5 times as efficient

as conventional combustion engines, at roughly 1/30th the energy density of diesel, this still means that lithium ion banks need to be between 6-10 times the size of a diesel tank to travel the same distance.[xv]

HEAVY DUTY VEHICLES

Similar to MDVs, daily distance requirements, load amounts, number of start/stop cycles, and stationary energy requirements all factor into choosing the appropriate fuel for an HDV. For example:

- Transport trucks require large tanks for long distance travel and potentially large payloads, but have few start/stop cycles and little stationary energy.
- Forestry trucks require large loads and travel moderate distances, but do not need stationary energy.
- Drayage trucks usually travel relatively short distances between ports and train yards, but require very high loads and several start/stop cycles.
- Waste haul trucks travel primarily in urban centres, stop at many locations, and will occasionally need power for compacting and lifting bins, but this work can be done without significant idling.

HDVs are primarily used for long-haul transportation, though some vehicles (fewer than 10%)[5] are used for other purposes, including drayage and rail boxcar transport related to shipping. The shorter distances travelled by drayage and rail transport make these vehicles suitable to use CNG, RNG or renewable diesel. A mid-sized community that hauls waste and operates buses can often support a CNG refueling station. FortisBC can install and cover the costs to install CNG refuelling stations if annual diesel usage is above 200,000 L. [xvi] Some station owners also provide third party access to natural gas fueling (CNG and LNG).

In terms of purchase cost, most alternative fuel heavy duty vehicles (HDVs) will be purchased new because aftermarket technologies are generally not suitable for engine conversions. CNG/RNG HDVs require an incremental $60k-$100k capital cost.[xvi] Electric, hybrid electric, and hydrogen vehicles also require new purchases, and these options raise the capital cost significantly. Hydrogen in particular does not reach financial parity when compared to diesel.

Smaller communities can increase the economic case for purchasing an HDV by using it for multiple purposes, or by working with neighbouring communities to collectively purchase a vehicle that can provide services to all participating communities. When analyzing appropriate technologies against the same four criteria used for MDVs[6], HDVs are also considered well suited to CNG/RNG options, and to hybrid electric technology. LNG may be suitable for specific HDV applications where fuel does not stay idle for extended periods (several days) because it can evaporate.

Local governments can support the adoption of new HDV fuels and technologies through collaboration with different levels of government, the private sector, and utilities. Locating refueling stations just within major urban centres will not support long haul transport – a network of stations needs to be created. Proponents may want to mimic approaches used for passenger EV charging station network collaborations, using similar planning approaches and funding streams to accelerate project development time and reduce costs. This approach is especially important for hydrogen fuel or electric vehicles because current battery technology mean that their range is limited compared to other fuels. In rural areas, taking a regional or higher level approach to planning the location of refueling stations is an efficient use of financial resources.

CARBON CREDITS, FUNDING & INCENTIVES

[5] Source: Table R010, Canadian Vehicle Survey, 2009 Annual Averages (The Canadian Vehicle Survey (CVS) was terminated in 2011. Motor vehicle activity data are no longer available from this survey beginning with the 2010 reference.)

[6] Daily distance travelled, load requirements, frequency of start/stop cycles, and stationary energy needs.

BC'S LOW CARBON FUEL STANDARD

BC's Greenhouse Gas Reduction (Renewable & Low Carbon Fuel Requirements) Act (GGRR) and the Renewable & Low Carbon Fuel Requirements Regulation (RLCFRR) were introduced to reduce British Columbia's reliance on non-renewable fuels, help reduce the environmental impact of transportation fuels, and contribute to a low-carbon economy.

The GGRR enables public utilities in BC to offer zero-interest loans or grants to end-use customers to adopt lower carbon fuels by providing monetary incentives toward purchasing new natural gas vehicles. The GGRR was enacted in 2012 and is set to expire on March 31, 2022. To date, the regulation has enabled FortisBC to incent and put into service over 850 natural gas powered vehicles since 2012.

BC's Renewable and Low Carbon Fuel Requirements Regulation is credited with 25% of BC's emissions reductions from 2007-2012. [xvii]

BC's Low Carbon Fuel Standard (LCFS) specifies mandatory reductions in the GHG intensity of fuels sold within a jurisdiction. By setting a required emissions performance fuel suppliers have flexibility in reaching the standard. Suppliers and users of lower-carbon transportation fuels – including biofuels, propane, hydrogen, compressed, renewable and liquid natural gas, and electricity — can earn carbon credits.[xvii]

Part 2 of the Act requires fuel suppliers to include renewable content in the gasoline and diesel fuels supplied in BC for transportation or heating. Since 2010, fuel suppliers have been required to include five percent renewable content in the gasoline pool. In the diesel pool, the renewable requirement is four percent.

Part 3 of the Act requires fuel suppliers to reduce the greenhouse gas emission (carbon) intensity of the transportation fuels they supply. Compliance is measured in terms of credits and debits, which represent the difference between the carbon intensity of the fuel and the current Part 3 (low carbon fuel) requirements for the relevant fuel class. The BC Government has established a schedule of reductions that will reduce the carbon intensity of the transportation fuel mix in B.C. by 20% by 2020 relative to 2030. Under Section 6 of the Act, Part 3 fuel suppliers generate credits by supplying a fuel with a carbon intensity below the prescribed carbon intensity limit, and incur debits when supplying a fuel with a carbon intensity above the limit (e.g. petroleum-based gasoline and diesel).

Part 3 fuel suppliers may also enter into agreements to take actions to reduce GHG emissions by generating Part 3 fuels sooner than would occur without the agreed-upon action. Fuel producers also may apply for a unique carbon intensity based on the lifecycle parameters of the specific fuel they produce. Once this carbon intensity is approved, anyone who supplies that fuel must use that approved carbon intensity and corresponding BC low carbon fuel code. Refer to Table 2 (page 10) for approved carbon intensities of alternative fuels sold in BC.

FUEL COSTS AND CARBON CREDITS

Table 3 describes in more detail the alternative fuels available for transportation in BC. Relative fuel cost is provided in the table's last column in diesel litres equivalent (DLE).

Table 3: Alternative Fuels and Technologies for Commercial Transportation (DLE = Diesel Litre Equivalent)

Fuel	What is it	Market readiness, application	Cost
Biodiesel	Converted from waste vegetable and animal oils, can replace diesel directly	Currently available as B## (e.g. B10 = 10% biodiesel) Few retail locations available. Operational limits in colder weather due to higher congealing point than diesel.	Retails for similar prices to diesel or at a slight discount **(2018 diesel price in BC is $1.40/L)**.[xviii]
CNG – Compressed Natural Gas	Pressurized to 3,000 – 5,000 psi and stored in tanks	Fully commercialized. Available at 7 stations across southern BC Additional facilities in development.	CNG cost in BC: **$0.50 - $0.75/DLE** without LCFS credits[xix] Potential LCFS credits: **$0.05 – $0.07/DLE** CNG cost with LCFS credits: **$0.43 – $0.68/DLE**
Electricity	Electricity from the grid charges vehicle batteries	Charging standards for MDV and HDV currently evolving. Current charging stations in BC are designed for light duty vehicles. Options exist for school / transit buses and some MDV applications. Announcements have been made with manufacturing expected to begin on first HDV electric vehicles.	Cost depends on local utility and type of charging station **($0.335/DLE in BC)***
Hybrid Electric	Mix of electric and combustion sources for propulsion	Available as retrofit for MDV.	Fuel cost savings of 30% vs. diesel, or total fuel cost of **$0.98/DLE** @ current diesel fuel prices.[xx]
Hydrogen Gas	Can be produced from electrolysis or reformation of fossil fuels	Facility in Vancouver, opened June 2018 , several more stations planned in lower mainland and Capitol region with Hydrogen from electrolysis priced at the equivalent to gasoline on a unit of energy basis.	2016 Costs **$2.98 - $5.35/DLE**[xxi]
RNG - Renewable Natural Gas**	Commit to supporting a volume of RNG equivalent to use or a portion of use.	Five generating facilities in partnership with FortisBC. Two additional facilities in development.	RNG is a 3rd-party certified carbon-neutral product, and BC's low carbon fuel standard provides for credits to offset cost. RNG cost in BC: **$0.87/DLE without LCFS credits** [xix] Potential LCFS credits of **$0.30 – $0.40/DLE**. [xvi] RNG cost with LCFS credits: **$0.47 – $0.57/DLE**

* Assumes Blended BC Hydro rate of $0.1181/kWh, 10 kWh/1 DLE, and fuel efficiency ratio of 3.5:1 for Electric vs. Diesel[xxii]

**RNG for this report is considered as a substitute for CNG, and is therefore reliant on CNG infrastructure

FLEET FUEL SWITCHING

Local governments with fleet vehicles that use or can be converted to CNG can become carbon neutral by switching to RNG and receiving a credit against their carbon tax payment.

Over 10,000 FortisBC residential and commercial customers (2019) pay the premium associated with RNG; however, this allows them to receive a credit of $1.99/GJ against their carbon tax payment and make progress towards their

corporate or provincial GHG reduction targets. In May 2018, the City of Surrey expected that switching from CNG to RNG will help meet its Corporate Emissions Action Plan emissions reduction goal of 20% by 2020. [xxiii]

In April 2019, TransLink (Metro Vancouver's transit provider) announced that it will source RNG for its natural gas bus fleet. Using CNG delivers a fifty percent reduction in fuel costs over diesel, and switching to RNG reduces emissions by an additional 80% over CNG. [xxiv]

PARTNERING ON RNG GENERATION PROJECTS

Renewable natural gas is generated by capturing biogas from decomposing organic waste, purified and sent into natural gas distribution lines. BC local governments pay a carbon tax of $30 per tonne via their commitment to becoming carbon neutral through the BC Climate Action Charter. BC's Climate Action Secretariat has acknowledged that switching to RNG displaces natural gas with a carbon neutral fuel. Local governments can reduce GHG emissions and costs through generating and/or using RNG.

Local governments are well placed to enable RNG source development because of their access to organic and liquid waste feedstock. RNG generation could provide a cost effective and strategic alternative to meeting climate and waste diversion targets. In BC, there are several existing municipal renewable natural gas projects using a range of feedstock managed by local governments, including landfill gas, organic solid and liquid wastes. [xxv] Some examples are:

Delta, B.C. – Digester

Kelowna, B.C. – Landfill

Richmond, B.C. – Wastewater treatment plant

Salmon Arm, B.C. – Landfill

Surrey, B.C. Biofuel facility

INCENTIVES & PROJECT FUNDING

BC local governments can access a large array of funding sources for transportation initiatives, some of which are highlighted in Table 4. Note that this is not an exhaustive list, and meant only to demonstrate the breadth of sources available. The CEA Funding Guide outlines a comprehensive list of over 40 types of funding sources for communities; the following table provides a sample of 2018 transportation-related grants available.

Table 4: Transportation Funding Sources

Source	Details
FortisBC	Offers grants of up to 75% for incremental cost over diesel of new HDVs and MDVs that use CNG or LNG. $40 million of incentive funding for RNG. Up to 100% of engineering costs and 50% of labour for construction of CNG or LNG maintenance facilities. Refueling stations can be constructed for fleets of varying sizes depending on fueling characteristics and requirements.[xvi] Other incentive programs available for LDVs, marine, mining, and power generation as well.
Clean Energy Vehicles for BC Program - SUVI	The Speciality-Use Vehicle Incentive (SUVI) Program offers rebates of up to $50,000 for buses, port vehicles, forklifts, low speed vehicles, and motorcycles.
Federation of Canadian Municipalities (FCM)	Offers an array of funding grants from the Green Municipal Fund, Municipalities for Climate Innovation, and Asset Management Program
Gas Tax Fund	Gas tax funding is highly flexible in how it is used and is provided twice a year.
Rural and Northern Community Infrastructure	This new funding source is comprised of several funds, to begin rollout in 2018-19. Some transportation-applicable sources include the Reducing Diesel Use Fund and Arctic Energy Fund.
National Trade Corridors Fund	This fund seeks to support the flow of goods and passengers by reducing bottlenecks, as well as to address climate change by supporting new technologies and innovation
Natural Resources Canada (NRCan)	Federal funding program is available under the NRCan Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative
Canada Infrastructure Bank	A new loans and equity investment funding source that seeks to spur public transit and trade/transportation corridor projects that have revenue-generating potential.

Sources: (Municipal Advocacy Solutions, 2017) (CEA, 2018) (Transport Canada, 2018) (FortisBC, 2018)

LOCAL GOVERNMENT ACTIONS

Community Energy Association's model for reducing emissions in commercial (heavy and medium duty) transportation includes four strategies (Figure 2). This guide addresses how local governments can shift to low carbon fuels in their own operations and encourage the commercial sector in their communities to decarbonize as well.

The remainder of the guide is structured around the ways local governments can influence the decarbonization of fleets: Lead, Enable, Invest & Earn, Manage, and Promote.

Figure 5: Five Local Government Actions to Decarbonize Medium and Heavy Duty Fleets

LEAD

Local governments have direct control over the management, operation, and procurement of municipal fleets and equipment. Fleet managers monitor and manage fuel consumption, vehicle purchasing, personnel use of assets, and employee training, allowing local governments to have significant control over fleet vehicle emissions. Managing a local government fleet with the goal of reducing GHG emissions also demonstrates leadership in the community. Local governments that own medium and heavy duty fleets can demonstrate different approaches to decarbonizing these fleets. Possible actions include:

a. Investing in a low carbon fleet
b. Improving automation, logistics, fleet optimization and back-haul opportunities
c. Driver efficiency training

Figure 6: Surrey RNG Waste Collection Truck (Source: City of Surrey, 2019)

Local governments that own fleet vehicles can purchase alternative fuel vehicles and implement fleet optimization practices. Local governments that contract out services that require medium and heavy duty vehicles can embed carbon reduction into procurement policies by specifying a low carbon fuel requirement during contract review. Some examples are:

In British Columbia

- In 2012, Surrey entered into a seven-year waste-disposal contract with Progressive Waste Services that requires the exclusive use of renewable natural gas-powered waste hauling (HDV) vehicles. This was a first for municipalities in Canada and for Progressive Waste, a major waste management company. These trucks emit 23% less carbon emissions and 90% less air particulates, compared to regular diesel trucks.
- In 2018, City of Vancouver, implementing actions recommended in their Fleet and Equipment Replacement Plan and Renewable City Action Plan, issued a three-year contract to replace 44 medium and heavy-duty internal combustion engine fleet trucks with electric trucks. The City received responses from four (4) vendors:

BYD Motors, Inc. (BYD), Cullen Western Star, on behalf of Mitsubishi (Mitsubishi), First Priority Green Fleet (First Priority), and Enviro-tech Drive Systems (Enviro-tech). By replacing end-of-life medium and heavy duty diesel and gasoline powered trucks with medium and heavy duty electric trucks, it is projected that the City will see a 1,200 tonne reduction in annual fleet CO2 emissions. [xxvi] According to FortisBC, the City has also purchased 33 new CNG refuse trucks and replaced 5 sewer trucks with CNG vehicles.

- Three BC Kootenay Regional Districts partnered on the Carbon Neutral Kootenays project, leading to the development of the guide *Fuel Efficiency for Municipal Fleets: A handbook for achieving efficiency and emission reductions in the municipal fleet,* which describes a range of actions local governments can take to reduce fleet emissions from medium and heavy duty vehicles, including driver training.[xxvii]
- *BC Greenhouse Gas Reduction Act* and the *Renewable and Low Carbon Fuel Requirements Regulation* and the Greenhouse Gas Reduction (Clean Energy) Regulation allows BC's utilities to invest in clean transportation and infrastructure. FortisBC currently provides incentives to convert medium and heavy-duty fleets from diesel to CNG.[xxviii]

In Canada

- In 2017, the City of Calgary piloted a questionnaire specifically tailored to soliciting information about the corporate sustainability practices of suppliers that provide products and services related to the City's fleet.[xxix]
- The cities of Montreal & Laval purchased 40 electric transit buses, to be rolled out in 2019. Laval plans to take its bus fleet entirely electric by 2023, and Montreal by 2025. Montreal also ordered 830 diesel-electric hybrids to be rolled out in 2020. The electric buses were less expensive than the hybrids.[xxx]
- The City of Ottawa awarded a refuse contract to Waste Management Co. in 2012 and dedicated a collection district with the condition that the collection trucks be run on CNG. The fleet consists of 41 CNG trucks that have contributed to a $640,000/yr. annual savings and an annual GHG reduction of 900 tCO_2e/yr., or 22 tCO_2e/yr. per truck.[xxxi]

In US / Europe

- California Air Resources Board is piloting two battery-electric Class 8 drayage trucks with hydrogen FCV range-extenders will be introduced in either late 2018 or early 2019 for 1-year in southern California.[xxxii]

City of Surrey CNG to RNG Fleet

The City of Surrey partnered with FortisBC and Progressive Waste Solutions, introduced 36 CNG-fuelled garbage trucks in 2012, which will grow to 52, reducing GHG emissions by an average of 419 tCO_2e/yr.[xxxiii] The RNG is sourced from the City's closed-loop organic waste management system, constructed at a cost of $68 million, **with no tax increases or additional fees for the public.** The system generates up to 49,000 tCO_2e/yr. of RNG, enough to completely displace CNG in the garbage truck fleet as well as the city's overall corporate carbon footprint of 21,000 tCO_2e/yr. Funding was provided by PPP Canada Fund (25%), and private sector partner Orgaworld (75%).[xxxiv]

City of Surrey RNG Fleet & Organic Waste Facility
52 garbage trucks converted
2 new CNG dump trucks ordered
419 tCO_2e/yr. saved with CNG
Organic Waste facility cost: $68 million
49,000 tCO_2e/yr. RNG generated
Entire corporate carbon footprint offset

City of Kamloops CNG Bus Fleet

The City of Kamloops converted 25 of its 44 heavy-duty diesel buses to CNG in 2015. After evaluating operational costs of the initial fleet, it was found that the fleet maintenance cost was less than 40% of that projected in the business case ($0.30/km vs. $0.79km). These results lead the city to convert its remaining 19 buses to CNG. Annual operational cost savings for the conversion of the remaining 19 buses is estimated at $290,000/yr. for 2017, or approximately $670,000/yr. for the entire fleet.[xxxv]

City of Kamloops CNG Fleet
44 buses converted
Garbage and sewer truck converted
(GHG savings not disclosed)
Operational costs <40% of original
$670,000/yr. saved

Table 5 shows a task list that could be offered to support feasibility and action plan development for local governments that wish to assess their low carbon fleet options:

Table 5: Task List for Assessing Low Carbon Fleet Options in Local Governments

Fleet State of Readiness

- ☐ Get ready: Plan, determine fleet needs, build business case, conduct research. If considering CNG or RNG vehicles, work with FortisBC on CNG or RNG fueling feasibility and review relevant fleet incentives.
- ☐ Get set: Build local leadership and capacity, collaborate, partner with stakeholders.
- ☐ Go: Develop funding strategy, confirm governance aspects and partnership agreements.

Corporate Behaviour

- ☐ Update the Corporate Fleet Purchasing Policy to favour low carbon vehicles and include HDV and MDV.
- ☐ Ensure existing fleet is right sized
- ☐ Improve fuel efficiency of current fleet.
- ☐ Optimize current operations
- ☐ Optimize vehicle routing
- ☐ Offer regular employee driver training sessions
- ☐ Work with local utility to employ an Energy Manager; develop a low carbon fleet feasibility, review and management plan.
- ☐ Lead by example to encourage community wide low carbon vehicle use.

Role of Low Carbon Vehicles

- ☐ Determine capital cost required to convert or replace vehicles
- ☐ Determine needs of fleet vehicles and whether low carbon vehicles will work in the geographical setting
- ☐ Note local air quality. Consider it sufficiently protected / improved through fleet management.
- ☐ Phase out conventional combustion engine vehicles for alternative fuelled vehicles
- ☐ Determine training scheme for employees to use low carbon vehicles
- ☐ Develop a matrix for each current fleet vehicle: fuel type, daily distance travelled, return to base schedule, long distance needs, duties performed, right size, weight of load needs, load capacity.
- ☐ Estimate vehicle fuel savings for conversions through a fuel savings online calculator.
- ☐ Estimate GHG savings on vehicle fuel conversion (See *2016 BC Best Practices Methodology for Quantifying Greenhouse Gas Emissions*).
- ☐ Review opportunity to establish corporate or community use electric charging sites and CNG/LNG refueling stations
- ☐ Take note of local waste hauler and transit vehicles for a regional approach to fuel switching.
- ☐ Review local sources of low carbon fuels and their proximity to the corporate fleet.
- ☐ Source local expertise and determine ways to leverage information from the private hauling industry

Financing

- ☐ Budget to raise capital cost to replace or convert vehicles to low carbon fuels.
- ☐ Review grants available

Collaboration

- ☐ Initiate discussion with stakeholders
- ☐ Engage the community
- ☐ Invite neighbouring fleets to collaborate on low-carbon solutions: BC Transit, School Districts, Ministry of Transportation and Infrastructure, Regional District, FortisBC and other utilities, Health Authority, contracted Waste Haul services, private fleets
- ☐ Build partnerships with neighbouring local governments, First Nations, Public Service Organizations and private sector.

Education and Persuasion

- ☐ Host low carbon vehicle transportation fairs or events, in conjunction with green home show
- ☐ Invite low carbon vehicle drivers to employee and community show and ride sessions
- ☐ Celebrate low carbon vehicles: use as parade vehicles, showcase in newsletters
- ☐ Provide low carbon fuel employee training
- ☐ Join E3 Fleet program (Energy Environment Excellence)
- ☐ Collaborate with fleet and transportation partners.

Potential Community Economic Development and Benefits

- ☐ Low carbon fuel use at municipal fleet level could attract regional fleet services and related companies to form a transportation hub
- ☐ Will build local low-carbon fuel expertise and serve surrounding communities
- ☐ Reduction in community wide GHG emissions from the transportation sector
- ☐ Potential corporate and community cost savings from reduced fuel costs over time
- ☐ Establishment of a low carbon fueling station will increase local tax base or non-tax revenue stream
- ☐ Enhanced community profile and branding

ENABLE

Local governments can influence the type and location of alternative fuel stations. The City of Surrey amended the city's zoning bylaw to require that any new gas stations include alternative vehicle fueling equipment. In the bylaw, "alternative fuel infrastructure" means any one of the following:

(a) Level-3 electric vehicle charging station (also known as a DC fast charger), or its equivalent;

(b) Fast-fill compressed natural gas (CNG) vehicle refuelling station;

(c) Hydrogen vehicle refuelling station; and/or

(d) Liquefied petroleum gas (propane) vehicle refuelling station.

Local governments can be proactive in identifying possible alternative fueling stations by working with FortisBC to identify possible sites for CNG or multi-fuel hub stations that include various fueling options such as CNG, RNG, LNG, electricity and hydrogen. Municipalities, local fire departments, Transport Canada, Environment Canada and other Ministries of both Federal and Provincial Governments may have approval/permit requirements for other aspects of alternative fuelling station operations such as the business, overall site and non-dispensing equipment.

Capital Regional District partnered with BC's Ministry of Energy, Mines and Petroleum Resources and the University of Victoria assess the performance of fuel cell vehicles in their fleet and to develop a hydrogen fuelling station. Without the assurance of the CRD's fuel cell electric vehicles (FCEV) using the station, there would be no incentive for industry to consider building this type of fueling station. Likewise, automakers with plans for broader market deployment of FCEVs will only consider regions where there is hydrogen fuelling infrastructure. CRD's pilot project is enabling the capital region to kick-start the transition to widespread use of FCEV.

Figure 7: Electric Bus in Montreal (Source: Montreal Gazette, 2019)

INVEST & SAVE

Local governments can invest in the development of alternative fuels. In BC, FortisBC is actively seeking new opportunities to generate RNG. In 2008, the Province commissioned a study to assess the amount of methane generated by BC landfills, which are one source of RNG supply[xxxvi]. Table 6 includes the modelled results of the amount of methane generated by the 35 landfills included in the study.

Table 6: Modelled Study Results of Methane Generation by 35 BC Landfills

Year	Tonnes of Methane	Equivalent Tonnes of CO_2 (CO_2e)	Equivalent Number of Automobiles
2008	118,000	2,474,000	825,000
2012	137,000	2,872,000	957,000
2016	147,000	3,079,000	1,026,000
2020	153,000	3,204,000	1,068,000

The Greenhouse Gas Reduction (Emissions Standards) Statutes Amendment Act focuses on reducing GHG emissions while increasing opportunities in the bioenergy sector.[xxxvii] The Act provided authority for the Landfill Gas Management Regulation, which was enacted in January 2009. Waste-management operations (including landfills, composting facilities and sewage treatment plants) are required to manage GHGs by reducing emissions or capturing them. This provides opportunity to generate energy and income from the emissions and through carbon credits.

Aggregation of municipal organic wastes and agricultural waste can also provide opportunities to generate RNG in smaller and rural communities. Current regulations restricting the transport of agricultural waste suggest that municipal solid waste should be transported to agricultural sites for processing. Proximity to a natural gas main line further supports a good business case.

Private sector partners can be leveraged to support these opportunities. The Surrey Biofuel case study (noted earlier in the LEAD section), included a private partner who was willing to construct a processing plant in exchange for access to the fertilizer it would produce. FortisBC supported the project by upgrading biogas to RNG. Surrey is paid for its contribution through a 20 year contract with FortisBC (FortisBC will purchase RNG, manage the supply volumes and resell the RNG at the same price back to the City) and through the sale of the fertilizer product to the private partner. Surrey uses the revenue from the project to offset waste tipping fees and pay down the cost of capital. The RNG produced is used to fuel Surrey's waste hauling trucks and supply heat to the city's buildings.

Local governments in B.C. are subject to a carbon tax of $40 per tonne of carbon dioxide equivalent emissions. Local governments that divert organic waste from landfills qualify for greenhouse gas offsets, which can help finance projects. By signing the Climate Action Charter and committing to become carbon neutral, the City of Surrey is eligible for the Climate Action Rebate Incentive program and will receive carbon credits for the innovative biofuel program. In 2017, Metro Vancouver received greenhouse gas emission reduction credits of 534.9 tonnes from methane capture at the Coquitlam landfill.[xxxviii]

MANAGE

Transportation demand management for medium and heavy duty trucks embraces strategies for increasing the trip efficiency of freight and commercial transport. In urban areas, municipalities can actively support cargo bikes for local deliveries through policy and preferred parking. *Pedal Express* is a human-powered cargo delivery service in the San Francisco Bay area. It operates a fleet of cargo bicycles capable of carrying up to 700 pounds in watertight containers. Common deliveries include meals and baked goods, books packages and post office box mail.[xxxix]

Municipalities can also restrict truck travel to certain routes and times. In Burnaby, vehicles which exceed 13,600 kilograms (30,000 pounds) gross vehicle weight are restricted to designated roads described on the Burnaby Truck Route Map. The City of Delta has implemented time-of-day restrictions on certain roads.[xl]

In urban areas, transportation demand management often focuses on limiting investment in new roads, reducing the number of vehicles and supporting alternative and active transportation modes. However, when it comes to efficient freight delivery, it can be advantageous to invest in road infrastructure.

Because of their large size and slower acceleration, heavy trucks impose more congestion per unit of travel than lighter vehicles. Freight vehicles are a small portion of total urban-peak traffic (operators tend to schedule their trips to avoid urban-peak driving to minimize congestion delays), but heavy trucks constitute a large portion of traffic on some corridors, such as highways to ports and major industrial areas. [lxvii]

BC constructed the South Fraser Perimeter Road (Highway 17) to support efficient freight movement between major highways, bridges, industrial areas, ports and the border. The road will encourage efficient truck movements and reduce emissions by limiting the number of stops trucks needs to make.

Road investments can be further supported by clustering common destinations together, reducing the amount of travel required for goods distribution. With this in mind, in 1993, the City of Vancouver undertook a comprehensive review of the role and function of its industrial land stock. The study's conclusions recommended preserving remaining stock, and City Council subsequently endorsed a policy of industrial land retention in 1995. Both the City of Vancouver and the Greater Vancouver Regional District have a policy of "planning by proximity", to minimize transport demand by planning for adjacent, complementary land uses.

About 80 German cities have set up “City Logistic” projects whereby shipments are consolidated outside the city limits and better organized within the city. The municipality, chambers of commerce and large haulers set up a trans-shipment facility and a new company that provides coordinated delivery services within the city. The service uses vehicles with state-of-the-art air and noise emission reduction features. To expand the service, geographic coverage can be increased, and services like cold transport and retail delivery may be added. To be competitive, the quality of service needs to be better than average. This type of service benefits municipalities (less spending on roads), citizens (less noise and pollution), railways (attract new inter-city traffic), and shippers (reduce costs).[lxvii]

PROMOTE & INFORM

The Municipal Commercial Vehicle Licensing (CVL) Program is established by provincial statute to provide a source of revenue to municipalities to offset associated costs such as roads maintenance, signage, snow removal, and parking control. Any vehicle using municipal roads and operating for commercial purposes in a participating municipality must annually purchase and display a commercial vehicle licence decal.

Local governments can use the opportunity of issuing licenses to promote alternative fuels and efficient driving education. Materials provided could highlight a recent pilot program undertaken by UPS in partnership with FortisBC involving the conversion of its delivery vehicles to CNG and the construction of a CNG fuelling station. Globally, UPS has invested more than $1 billion in alternative energy solutions as of 2018. Currently 40% of the UPS Canada fleet runs on alternative fuels, including the addition of seven new CNG highway tractors and 40 delivery trucks.[xli]

Vancouver goes CNG with UPS

UPS, in partnership with FortisBC, built its first Canadian CNG refueling station in Vancouver in 2018, while adding 40 CNG delivery trucks and 7 tractors to their growing CNG fleet, which currently accounts for 40% of their overall vehicles. [xlii]

UPS' Refueling Station & Fleet
First Canadian
UPS CNG Refueling Station
Additional 40 delivery trucks & 7 tractors added
40% of UPS fleet running on CNG

Canadian Linen Incorporates CNG and Logistics Technology

Through incentives from FortisBC, Canadian Linen purchased 20 CNG trucks to add to its Vancouver fleet in 2016, bringing them up to 36 CNG trucks, 16 propane, and 2 electric across Canada. Conversion is expected to reduce vehicle GHG emissions by 20-30% vs. diesel, while saving 25-50% in fuel costs. Through rollout of telematics technology, which coaches drivers on efficient and safe driving practices, vehicle idling has also been reduced by over 95%, while rerouting and improving delivery efficiencies reduced travel by over 550,000 km.[xliii]

Canadian Linen – CNG and Logistics
Purchase incentivized by FortisBC
20 CNG trucks added to Vancouver fleet
20-30% reduction in GHG annually
25-50% savings in fuel costs annually
Telematics reduced idling by >95%
550,000 km avoided from efficiencies

R&B Trucking Shifts to Diesel-Electric

Victoria-based R&B Trucking purchased a Class 5 diesel-electric hybrid refrigeration truck in 2009 as part of the Fraser Basin Council's Green Fleets program, with an all electric refrigeration system. It is expected to save 35% in fuel costs along with a reduction of 20 tonnes of GHG annually. E3fleet's Green Fleets program covered the cost difference between a conventional diesel and the hybrid vehicle, to a maximum of $20k per vehicle.[xi]

R&B Diesel-Electric Class 5 Truck

Part of E3fleet Green Fleets program

35% savings in fuel costs annually

20 tonnes GHG reduced annually

Coldstar Solutions CNG Highway Tractor Fleet

Through purchase incentives from FortisBC, which covered 75% of the incremental cost of a new CNG vehicle purchase Coldstar Solutions, which specialized in transport of refrigerated goods, purchased 10 Class 8 CNG highway tractors, making them the first fleet in Canada to run CNG highway tractors. Estimated savings from these trucks are over 380,000 L/yr. of diesel, resulting in a reduction of 360 tonnes/yr. of GHGs, in addition a fuel cost savings of 30-40%. After the success of this initiative, they have then purchased three 5-ton CNG trucks, and another 10 trucks planned for operation out of their Nanaimo location.[xliv]

Coldstar CNG Highway Tractor Fleet

First of its kind in Canada

10 Class 8 CNG tractors

380,000 L/yr. of diesel avoided

360 tonnes/yr. GHG avoided

30-40% reduction in fuel costs

CONCLUSIONS

With commercial transportation accounting for 31% of BC's transportation emissions, local governments have a critical role in mitigating transportation GHGs. MDVs are an important opportunity for local governments because 40% of MDVs are used in government fleets. Local governments have several tools available to facilitate change in their transportation portfolios: shifting vehicles to low-carbon or zero-carbon options, improving efficiency through driver training, fleet optimization, and by improving automation.

CNG, biodiesel, propane, and hybrid electric trucks are available. Although electric truck technology is advancing, it will take time to become a practical solution, in part because of cost premiums and the need for early adopters to prove viability. [xii].

RNG will work in all MDVs or HDVs that use CNG and any fueling station that delivers CNG can deliver RNG.

Hydrogen fuel cell vehicles have progressed technologically but remain less financially viable because of the cost premium and the lifecycle emissions profile of hydrogen is not yet compelling as a clean transportation fuel. The ongoing expansion of the hydrogen fueling network in British Columbia will begin to reduce barriers to hydrogen vehicle market adoption.

Whereas larger communities may have the volume to make single-purpose vehicles financially feasible, smaller communities may need to look at dedicating a vehicle for multiple tasks, or look at collaborative approaches with neighbouring communities to increase financial feasibility.

There are plenty of funding sources available provincially, federally, and from utilities, although communities should also examine multi-level efforts to improve both financial feasibility and to draw a wider array of funding by demonstrating regionally/provincially importance.

Local governments can also invest in the development of alternative fuels, such as biodiesel and renewable natural gas, in conjunction with organic waste or landfill programs. Other recommended actions are to install alternative fuelling stations to stimulate growth within the private sector, manage transportation infrastructure to limit new road construction and optimization of routes, and configure commercial licensing systems to favour alternative fuels and efficient driving education.

Though this report focused primarily on fuels, optimizing routing, operation, and vehicle efficiency are important, impactful and cost-effective ways to improve safety, fuel efficiency, and GHG reductions. When considering fuel switching, daily distance requirements, load amounts, number of start/stop cycles, and stationary energy requirements all factor into choosing an appropriate fuel for the necessary task.

APPENDIX A: MDV APPLICATIONS, FUELS & TECHNOLOGIES

Digitization is seen as the biggest market driver in the truck market going forward, with increasingly connected supply chains allowing for real-time route optimization and improved utilization of capacity. Urban logistics will also play a major role, as more sophisticated ordering and increased numbers of packages, particularly from online distribution chains like Amazon, necessitate logistics companies to relocate closer to urban centres. Distribution is typically carried out by HDVs for long-distance hauls, and light-duty trucks (LDTs) for the "last kilometre", diminishing MDVs' role in the delivery supply chain.[xiii] Despite the expected contraction for MDVs in the trucking industry, it's important to remember that 40% of MDV usage is for non-trucking purposes, mostly centered around public service vehicles, representing a relatively large proportion of MDVs from which municipal governments can directly affect change as a customer, rather than through policy.

Table A1: Medium Duty Vehicle Applications

Application	Daily distance	Load	# Start/stop cycles	Stationary Energy needs	CNG	RNG	Electric	Hybrid	Hydroge
Delivery	Long	Heavy	Very Many	Minimal	✓	✓	✓	✓	
Refrigeration	Medium	Very Heavy	Few	Maximum	✓	✓		✓	✓
Fire truck	Medium	Light	Some	Maximum	✓	✓		✓	✓
Bucket truck	Short	Medium	Few	Maximum	✓	✓		✓	✓
Towing	Medium	Heavy	Many	Medium	✓	✓	✓	✓	✓
Construction	Short	Heavy	Very Many	Maximum	✓	✓		✓	✓

AVAILABLE FUELS & TECHNOLOGIES

Relative new vehicle cost premiums over diesel and market readiness are depicted in the chart below. CNG/RNG conversion can also be completed on existing fleet vehicles to save capital costs and extend the life of current assets. Conversions are not readily available from diesel to electric or hydrogen.

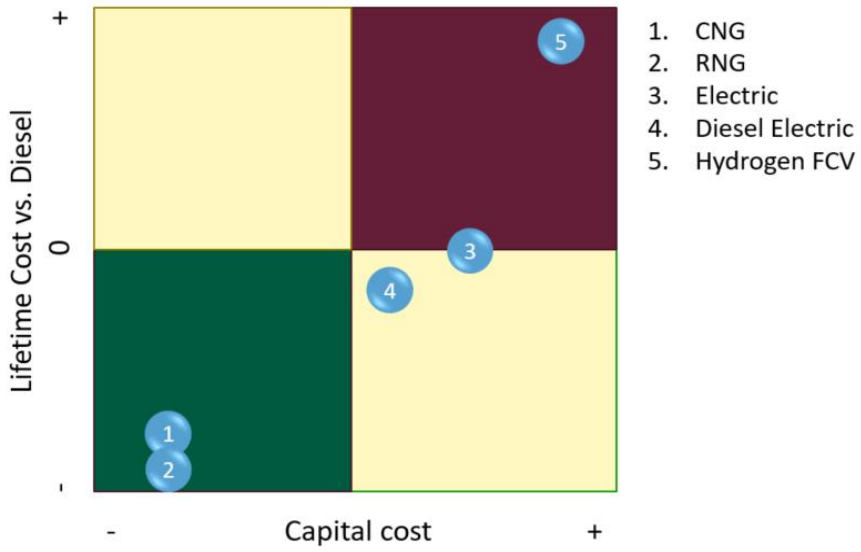
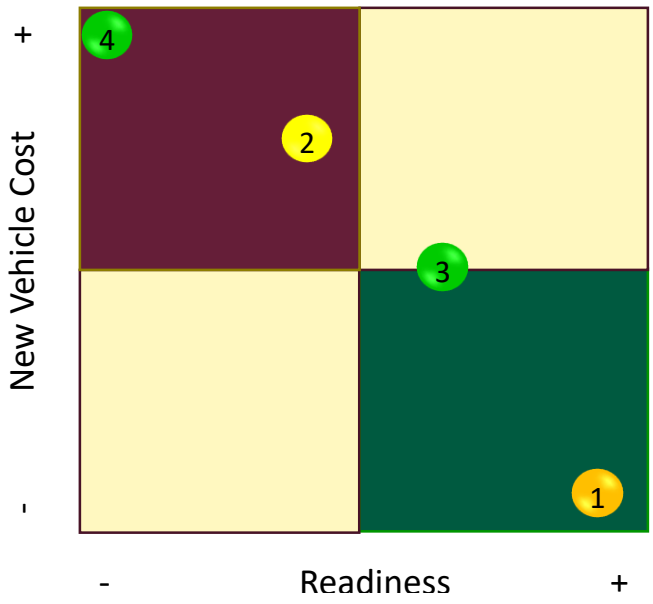


Figure A1: Medium Duty Vehicle Assessment for New Purchase



Range
- Red: < 150 km
- Orange: 150 – 249 km
- Yellow: 250 – 349

1. CNG/RNG
2. Electric
3. Diesel Electric
4. Hydrogen FCV

Figure A2: Medium Duty Vehicle Cost Analysis

Table A2: Medium Duty Fuel & Technologies

Technology	Capital Costs, Lifetime Comparison	Maximum Range (km)	GHG Reduction (%/yr. vs. Diesel)	Status as of 2018
Electric*	Capital: $100k above diesel[xlv xlvi] Lifetime: On par with diesel[xlvii]	370 [xlviii,xlix]	80-100, depends on electricity source	Chanje EVs introduced in 2017, 6 month UPS pilot program commencing in 2018 or 2019[l]. Daimler to test fleet of 30 vehicles in 2018, to start production in 2021.
Diesel-electric hybrid	Capital: $25k - $40k above diesel Lifetime: 5 – 17 year payback[li]	750	10-50[lii]	Technology readily available for over 20 years, 2,000 vehicles running in California, can be run with 20% biodiesel as well[liii]
CNG**	Capital cost (above diesel): $80k, $56k paid by FortisBC, $24k by customer Lifetime: 0.5 - 2 year payback, $60k – 200k lifetime savings	200	25-50	CNG fleets already in Canada operating on variety of applications (Waste, cleaning, school transport)[liv]
RNG**	Case specific example: $0.87/DLE without LCFS credits[lv] and $0.47 – 0.57/DLE with LCFS credits. [xvi]	200	100	FortisBC RNG now sits below electricity on BC's LCFS GHG intensity factor scale (11 gCO_2e/MJ vs. 19 gCO_2e/MJ)[lvi]
Hydrogen fuel cell (FCV)	N/A	320[xxviii]	25-100, depends on hydrogen source[lvii]	Demonstration-scale for delivery vans, construction equipment, and garbage trucks[lviii]

* Assumes 40,000 km/yr., 5.6 L equivalent/100 km
** Assumes $0.70/DLE, $75k capital conversion cost, $53k paid by FortisBC, $22k by customer
All values in 2018 $CAD unless otherwise stated, exchange rate of $1.3 CAD/$1 US

APPENDIX B: HDV APPLICATIONS, FUELS & TECHNOLOGIES

An important market factor to the future of the HDV industry going forward is digitization. Data analytics, autonomous vehicles, robotics, and blockchain technology will all factor into the future of industry logistics in improving process efficiency and decreasing delivery times. One example is the incorporation of electronic logging devices (ELDs) over paper logs. ELDs will record vehicle data such as location, date, time, distance driven, and engine hours. The goal of this initiative is to improve safety, reduce the rate of preventable accidents, and increase accountability of trucking companies. Canada has yet to adopt mandatory ELDs in HDVs, however this is expected to change as of the end of 2019.[lix]

A market-centric driver that must be addressed is driver capacity. Older drivers are retiring, while fewer young drivers are taking their places. Further, truck supply is low with freight demand rising. Ultimately, this will result in delivery rate increases. New technologies also serve as disruptors in the transportation industry. On-demand freight apps such as those by Uber, Convoy, and Amazon match trucking companies with shippers looking for freight that needs moving immediately.[lx]

Table B1: Heavy Duty Vehicle Applications

Application	Daily distance	Load	# Start /stop cycles	Stationary Energy needs	CNG	RNG	LNG
Trucking	Long	Heavy	Few	Minimal	✓	✓	✓
Refrigeration	Medium	Heavy	Some	Maximum	✓	✓	
Forestry	Low	Very Heavy	Some	Minimal	✓	✓	
Garbage	Low	Heavy	Very Many	Minimal	✓	✓	
Public bus	Low	Medium	Very Many	Minimal	✓	✓	✓
Drayage	Short	Very Heavy	Very Many	Medium	✓	✓	

HEAVY DUTY – AVAILABLE TECHNOLOGIES

Figure B1 illustrates the relative new purchase cost and range comparison for a variety of fuels for trucks and buses, Figure 7 shows the capital cost and lifetime vehicle cost vs. diesel, and Table 3 shows more details on each type of technology including range, status, and GHG reduction potential.

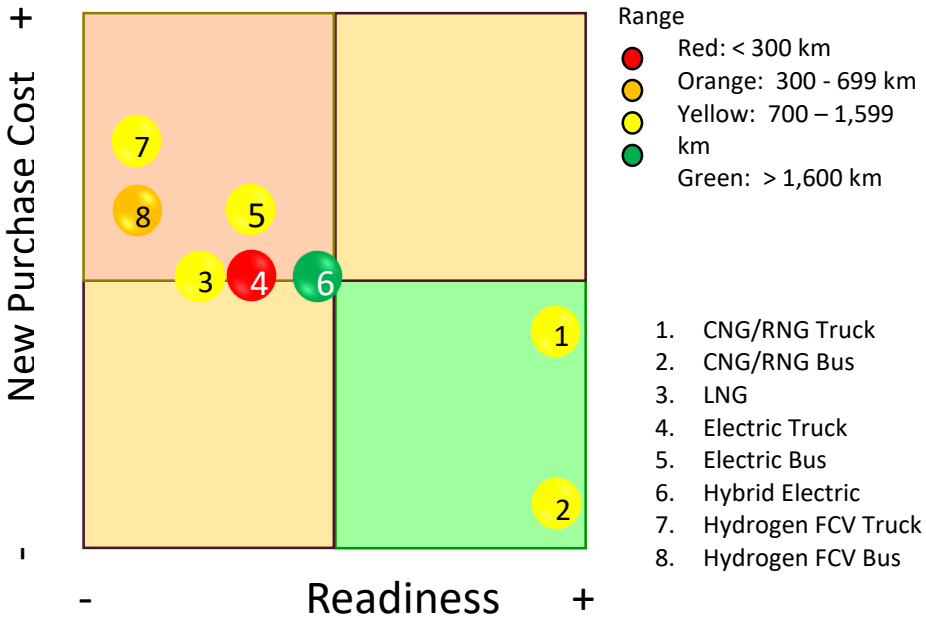


Figure B1: Heavy Duty Vehicle Fuel Assessment (New Purchase)

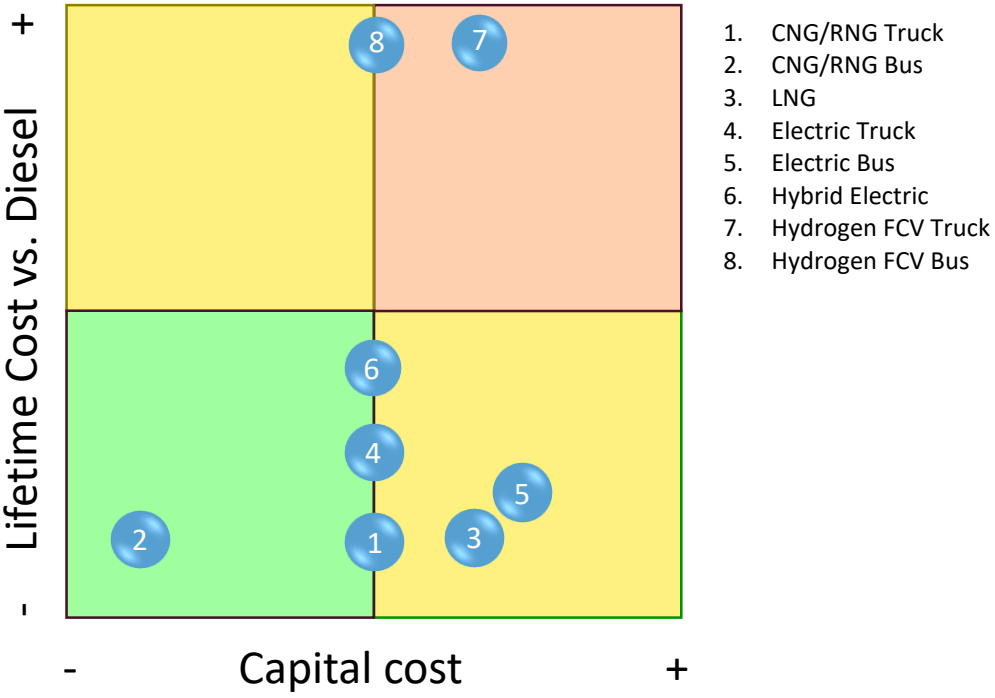


Figure B2: Heavy Duty Vehicle Cost Analysis

Table B2: Heavy Duty Available Technologies

Technology	Costs	Range (km)	GHG Reduction (%/yr. vs. Diesel)[1]	Status as of 2018
Trucks				
CNG	Capital conversion cost: $75k, $53k paid by FortisBC, $22k by customer Lifetime: 0.5 - 2 year payback, $60k – 200k lifetime savings [xvi]	3,000	20 - 40	Conversion kits up to 775 DLE now available, 15 refueling stations in BC,[xvi] Also long-haul CNG/LNG trucks now available.[lxi]
RNG	$0.87/DLE without LCFS credits[lxii] and $0.47 – 0.57/DLE with LCFS credits. [xvi]	350 – 1,600[lxiii]	100	RNG well suited for HDVs[lxiv]

Buses*				
Technology	**Costs**	**Range (km)**	**GHG Reduction (tCO_2/yr. vs. Diesel)**	**Status as of 2018**
Electric	Capital: $975k - $1.08m[lxv] Lifetime: Up to $525k savings	680 – 1,770	80*-100** Depends on electricity source	**Pilot-scale, new fleets in Montreal (40), Edmonton (25)**
Hydrogen FCV	Capital: ≈$1m[lxvi] Lifetime: Does not reach parity with diesel (fuel costs are higher than diesel)	450[lxvii]	40-100 Depends on hydrogen source	Only 1 bus remaining in Canada, 3 fuelling stations in development[lxviii], **BC Transit's FCV bus fleet sold 2014 due to high operating costs[lxix]**
CNG	Capital: $50k - $70k above diesel[lxx] Lifetime: 1 yr. payback period	500 – 1000 [xlilxx]	30[xli]	Technology well established. **Nanaimo, Kamloops, Red Deer, Hamilton, Metro Vancouver, and others have successfully switched.** Consideration must be given to cost of installing and maintaining CNG fuelling stations as well.
RNG	Additional fuel cost of >$0.27/L above CNG fuel, additional $10k/yr./bus @ 3.3 mpg equivalent	500 – 1000[iixliv]	100	TransLink to convert natural gas bus fleet to 100% RNG by 2024.[lxxi]

* For Alberta, assumes 900 g/kWh CO_2e[lxxii], 67,000 km/yr.[lxxiii], 130 kWh/100 km mileage[lxxiv]
** For Quebec, assumes 1.7 g/kWh CO_2e, 67,000 km/yr., 130 kWh/100 km mileage
*** 40' bus benchmark, 50,000 km/yr.
All values in 2018 $CAD unless otherwise stated, exchange rate of $1.3 CAD/$1 USD, 3% inflation

APPENDIX C: DECARBONIZING THROUGH FLEET MANAGEMENT

Effective communication with vehicle and machinery operators is important for the successful implementation of any vehicle or fleet-related action or policy. Newsletters or notice boards can be effective for those that read them, but regular and participatory communication ensures that the topic stays top of mind and that efficiency becomes a mainstream approach to operations.

For optimal buy-in and implementation of any action or policy, staff must have a sense of ownership. This can be achieved through active communication among staff and between employees and managers. Table 1 provides a number of communication ideas.

Table C1: Summary of Communication Approaches

Communication Approach	Details	Ideas
Pre-shift Tailgate Meetings	Opportunity to: • Highlight fuel efficiency techniques • Reminder on policies and actions adopted by the local government	• Focus on one fuel efficiency/vehicle operation theme per month/meeting. Possible topics: idling; speed; vehicle maintenance (tire pressure, oil changes), etc. • Provide regular opportunity for staff suggestions on fuel efficiency. • Provide regular updates on improvement/successes resulting from fuel consumption reduction initiatives.
Feedback/Input Opportunities	Two-way communication and feedback to ensure • Programs, actions or policies in place are monitored • Measured for success	• A suggestion box placed in a central location to invite staff to put forward ideas/suggestions to improve the efficiency of the fleet. • Offer rotating (i.e. monthly or bi-monthly) themed brainstorming opportunities with accompanying resources. For example, an “idling theme” may invite input around ways to reduce idling. • Example: Use staff expertise for input regarding fleet performance. Provide opportunity for comment on the appropriateness and functionality of each vehicle for the task it is assigned.
Lunch & Learns	Lunch break may be an opportunity: • to engage staff on a particular topic • to be more conducive to a brainstorm or discussion	• Arrange for a presentation from a machinery or fuel supplier, or a mechanic (local or in-house with expertise on fleet efficiencies. • Lunch-time workshop is a casual opportunity to present a detailed report on progress, or to delve deeper into tail gate meeting highlights (i.e. fuel efficient driving techniques; introduction of new technology pilot project, etc.).
Signage/Promotional Information	Extending communication into the community creates accountability for staff, managers and elected officials.	• Signage and stickers on fleet vehicles communicate the commitment to efficiency externally. See Communication Tools” section for free resources. • Report to Council progress made within the vehicle fleet to recognize success at the political and community level • Post signs and reminders in the lunch room, offices and garages vehicle fleet operators. See Communication Tools for free resources.
Government-wide Engagement	The most significant change in behaviour results when efficiency and conservation become engrained in the culture of an organization.	• Distribute ‘fuel efficiency’ tips on paystubs and other staff mailouts • Include information in internal newsletters, email updates. • Publish an annual or biannual newsletter dedicated to energy and emissions issues. • Challenge staff to carpool, bike and walk to work, or take public transit whenever possible. • Celebrate successes by publicly acknowledging achievements.

A wealth of resources available online can be obtained for local government use (examples below). Though simple and cost-effective to use these existing materials, local governments may prefer to design their own communication tools.

- Idle Free BC – Idle Free BC website contains materials developed by local governments across Canada. Bumper stickers, Works Yards signs, pamphlets and street signs can all be downloaded from the Idle Free BC website, and adapted for your community.

  http://www.idlefreebc.ca/resources/index.php

- Province of B.C. – Procurement, Supply and Services sector of the Provincial governments has developed an order form for community Idle Free signs. The order sheet can be accessed at the following link:

  http://pss.gov.bc.ca/dcv/. Signs are $25 each.

- Natural Resources Canada – The Office of Energy Efficiency has idle free and fuel efficiency promotional materials available for download and use by local government or community groups.

  http://oee.nrcan.gc.ca/transportation/idling/material/8895

  NRCan offers an online tool to compare and rank fuel efficiencies of vehicles sold in Canada. This tool will assist with communication of fuel efficiency and will support the Vehicle Replacement Policy with up-to-date comparisons of vehicle efficiency.

  http://oee.nrcan.gc.ca/transportation/tools/compare/compare-search-one.cfm

  This Fuel Consumption Calculator is used to track fuel economy and communicate successes in fuel efficiency. A calculator is available for both light duty and heavy duty vehicles.

  http://oee.nrcan.gc.ca/transportation/tools/fuel-trip-calculator/fuel-calculator-input.cfm?attr=8

- E3 Fleet – The E3 (Energy Environment Excellence) program offers resources and support for members, including Handbooks, technical expertise, fleet review opportunities and a rating program. Some support is also available for non-members.

  http://www.e3fleet.com

- Community Energy Association

  The CEA handbook, Fuel Efficiency for Municipal Fleets, compiles fuel efficiency and fleet management information in a concise fashion, and provides fleet managers and staff with tangible, implementable approaches to fuel and GHG emission reductions.

  http://communityenergy.bc.ca/download/621/

  Recommended actions include:

  - Fuel consumption tracking
  - Avoiding idling
  - Driver efficiency training
  - Driver behaviour
  - Fleet assessment and review
  - Vehicle maintenance
  - Routing review
  - Idle free technologies
  - Vehicle replacement policy
  - GPS/vehicle monitoring system

LIST OF ACRONYMS

BAU	Business as usual
CCS	Carbon capture and storage
CEA	Community Energy Association
CEEI	Community Energy & Emissions Inventory
CLF	Current legislation fulfillment
CNG	Compressed natural gas
DGE	Diesel gallon equivalent
DLE	Diesel litre equivalent
EV	Electric vehicle
GDP	Gross domestic product
GHG	Greenhouse gas emissions (there are several different anthropogenic GHGs and they have different relative impacts. When tonnes of GHGs are stated in the document the standard practice of stating this in equivalent of tonnes of carbon dioxide is followed.)
GVWR	Gross vehicle weight rating, used to determine the class of a vehicle
HDV	Heavy-duty vehicle
ICE	Internal combustion engine
LDV	Light-duty vehicle
LNG	Liquefied natural gas
LPG	Liquid petroleum gas (Propane)
MDV	Medium-duty vehicle
RNG	Renewable natural gas
VKT	Vehicle Kilometres Travelled
WTW	Well to wheels (refers to life cycle GHGs in freight trucking industry)

LIST OF TERMS

Class	Categories based on a vehicle's weight. Class 1-3 is light-duty, 4-6 is medium-duty, and 7-8 is heavy-duty
Drayage	Transport of goods over a short distance in the shipping industry, usually from a ship to warehouse
Duty Cycle	The time, distance, and load that a vehicle is tasked for in a defined period of time, usually per round trip or day
Efficiency	A measure of output against an input
Logistics	Also referred to as supply chain, this encompasses all steps required in the transportation of goods from source to consumer

REFERENCES

Autotrader. (2018). *New & Used for Sale*. Retrieved from Autotrader: http://www.autotrader.ca/heavy-trucks/all/hino/?rcp=15&rcs=0&srt=3&prx=-1&loc=v0b1m3&hprc=False&wcp=False&sts=New&inMarket=advancedSearch

Bachmann, C. e. (2014). Life-Cycle Assessment of Diesel-Electric Hybrid and Conventional Diesel Trucks for Deliveries. *Journal of Transportation Engineering, 141*, 1-8.

Bate, E. (2018). *Updated: UPS opens its first CNG fuel station in Canada*. Retrieved from Today's Trucking: https://www.todaystrucking.com/ups-opens-its-first-cng-fuel-station-in-canada/

BC Laws. (2018). Greenhouse Gas Reduction (Clean Energy) Regulation. Retrieved from http://www.bclaws.ca/civix/document/id/complete/statreg/102_2012

BC Transit. (2018). *Elkford/Cranbrook*. Retrieved from BC Transit: https://bctransit.com/cranbrook/schedules-and-maps/health-connections/elkford-cranbrook

Bebon, J. (2017). *Volvo Introduces New Heavy-Duty LNG Trucks*. Retrieved from NGT News: https://ngtnews.com/volvo-introduces-new-heavy-duty-lng-trucks

Boston, A. (2018, September). Executive Director, Renewable Cities. (P. Dehnel, Interviewer)

Cambridge Systematics. (2009). *Moving Cooler: Transportation Strategies to Reduce Greenhouse Gas Emissions.* U.S. EPA. Retrieved from http://bit.ly/2vX5HGq

Canada Cartage. (2017). Retrieved from What You Should Know About The Upcoming ELD Mandate in Canada: https://www.canadacartage.com/canadian-eld-mandate-facts/

Canadian Biogas Association. (n.d.). *Canadian Biogas Association*. Retrieved from Renewable Natural Gas Projects in British Columbia: https://biogasassociation.ca/index.php/about_biogas/projects_british_columbia

Canadian Gas Association. (2016). *Natural Gas - A Clean and Affordable Transportation Fuel.*

Canadian Linen. (2016). *The Clean Story*. Retrieved from Canadian Linen: https://www.canadianlinen.com/the-clean-story/environmental-highlights

Canadian Natural Gas Vehicle Alliance. (2015). *Study On Natural Gas Research and Development Priority Setting for Transportation in Canada.*

Carbon Neutral Kootenays. (2012). *Fuel Efficiency for Municipal Fleets, A Handbook for Achieving Efficiency and Emission Reductions in the Municipal Fleet.*

CBC. (2018). *Greyhound Canada to end bus service in Western provinces*. Retrieved from CBC: https://www.cbc.ca/news/business/greyhound-cancellations-alberta-manitoba-saskatchewan-british-columbia-1.4739459

CBC News. (2014). *BC Transit's $90M hydrogen bus fleet to be sold off, converted to diesel*. Retrieved from CBC: https://www.cbc.ca/news/canada/british-columbia/bc-transit-s-90m-hydrogen-bus-fleet-to-be-sold-off-converted-to-diesel-1.2861060

CEA. (2018). *Community Energy Association Funding Guide.*

Charged - Electric Vehicles Magazine. (2018). *Hamburg container terminal deploys autonomous electric container transporter*. Retrieved from Charged - Electric Vehicles Magazine: https://chargedevs.com/newswire/hamburg-container-terminal-deploys-autonomous-electric-container-transporter/

Chicago Area Clean Citites. (2014). *Ozinga Awarded Clean Cities Clean Fuel Champion*. Retrieved from Chicago Area Clean Cities: http://chicagocleancities.org/ozinga-awarded-clean-cities-clean-fuel-champion/

City of Richmond. (2017). *Richmond's Fleet*. Retrieved from City of Richmond: https://www.richmond.ca/sustainability/energysrvs/energy-emissions/Fleet/fleet.htm

City of Vancouver. (2018). *Contract Award for Supply and Delivery of Medium and Heavy Duty Electric Trucks Adminstrative Report.* Retrieved from City of Vancouver: https://council.vancouver.ca/20180606/documents/cfsc2.pdf

City of Vancouver. (2018). *Greening the City's Fleet*. Retrieved from City of Vancouver: https://vancouver.ca/green-vancouver/green-fleets.aspx

CivicinfoBC. (2019, April 25). *TransLink Introduces Renewable Natural Gas to its Bus Fleet*. Retrieved from CivicinfoBC: https://www.civicinfo.bc.ca/news?newsid=7598

CNGPrices.com. (2018). Retrieved from http://www.cngprices.com/station_map.php

CNGVA. (2018). *Success Stories*. Retrieved from CNGVA: http://cngva.org/natural-gas-vehicles-canada/success-stories/

Coldstar Solutions. (2014, October). Natural Gas Fleet Profile - CNG Highway Tractors.

Community Energy Association. (2011). *A Primer on the Transition to Electric Vehicles in Metro Vancouver.*

Community Energy Association. (2018). *Closing the Loop.*

CTV News. (2017). *Electric trucks emerging but still have a long haul*. Retrieved from CTV News: https://www.ctvnews.ca/autos/electric-trucks-emerging-but-still-have-a-long-haul-1.3679143

CTV News. (2017, April 17). *Hydrogen fuel cell cars face obstacle: Where to fill up?* Retrieved from CTV News: https://www.ctvnews.ca/autos/hydrogen-fuel-cell-cars-face-obstacle-where-to-fill-up-1.3371184

Cummins Westport. (2018). *Cummins Westport Heavy-Duty Natural Gas Engines*. Retrieved from Cummins Westport: https://www.cumminswestport.com/about-us

Deloitte. (2016). *Global Truck Study 2016 - The Truck Industry in Transition.*

E3Fleet. (2018). *Green Fleets Successes*. Retrieved from E3Fleet: https://www.e3fleet.com/green_successes.html

EERE. (2015). *EERE Success Story—Concrete Company Moving to Natural Gas with Clean Cities*. Retrieved from EERE: https://www.energy.gov/eere/success-stories/articles/eere-success-story-concrete-company-moving-natural-gas-clean-cities

Electrek. (2019, April 25). *Tesla delays electric semi truck production to next year*. Retrieved from Electrek: https://electrek.co/2019/04/25/tesla-semi-delay-electric-truck-production-next-year/

Environment & Climate Change Canada. (2016). *National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada.* Retrieved from https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/emissions-inventories-reporting/nir-executive-summary/National%20Inventory%20Report%20Executive%20Summary%202018.pdf

Environment and Climate Change Canada. (2018). E-Tables-Electricity-Canada-Provinces-Territories. Retrieved from http://data.ec.gc.ca/data/substances/monitor/national-and-provincial-territorial-greenhouse-gas-emission-tables/E-Tables-Electricity-Canada-Provinces-Territories/?lang=en

Equipment World. (2013). *Does it pay for contractors to run a truck or fleet on natural gas?* Retrieved from Equipment World: https://www.equipmentworld.com/does-it-pay-for-contractors-to-run-a-truck-or-fleet-on-natural-gas/

European Automobile Manufactures Associatin. (2017). *Reducing CO2 Emissions from Heavy-Duty Vehicles - An Integrated Approach.* Brussels.

Forbes. (2018). *The Four Biggest Freight Transportation Trends To Watch For In 2018*. Retrieved from Forbes: https://www.forbes.com/sites/theyec/2018/02/08/the-four-biggest-freight-transportation-trends-to-watch-for-in-2018/#31759645f16a

FortisBC. (2012). *Innovative new waste haulers deliver savings while removing greenhouse gases and noise*. Retrieved from FortisBC: https://www.fortisbc.com/MediaCentre/NewsReleases/2012/Pages/Innovative-new-waste-haulers-deliver-savings-while-removing-greenhouse-gases-and-noise.aspx

FortisBC. (2018). *Affordable Options*. Retrieved from FortisBC: https://www.fortisbc.com/NaturalGas/RenewableNaturalGas/AffordableOptions/Pages/default.aspx

FortisBC. (2018). *Clean Growth Pathway to 2050.*

FortisBC. (2018). *Incentive Programs*. Retrieved from FortisBC: https://www.fortisbc.com/naturalgas/business/naturalgasvehicles/howwecanhelp/incentives/Pages/default.aspx

FortisBC. (2018). *Medium and Heavy-Duty Fleet Incentives*. Retrieved from FortisBC: https://www.fortisbc.com/NaturalGas/Business/NaturalGasVehicles/Howwecanhelp/Incentives/MediumHeavyDutyFleetIncentive/Pages/default.aspx

FortisBC. (2018). *UPS® Canada increases its alternative energy fleet*. Retrieved from FortisBC: https://www.fortisbc.com/MediaCentre/NewsReleases/2018/Pages/20180621-UPS-Canada-increases-its-alternative-energy-fleet.aspx

Gerber, R. (n.d.). *Natural Gas Buses – A Cost, Operational and Environmental Alternative*. Retrieved from CUTA: http://cutaactu.ca/en/news-media/natural-gas-buses-cost-operational-and-environmental-alternative

Golder Associates. (2008). *Report on Inventory of Greenhouse Gas Generation From Landfills in British Columbia.* Retrieved from http://www.env.gov.bc.ca/epd/codes/landfill_gas/pdf/inventory_ggg_landfills.pdf

Government of Canada. (2018). *Greenhouse Gas Emissions*. Retrieved from Environment and Climate Change Canada: https://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=F60DB708-1

Government of Canada. (2019, 06 10). *Government of Canada*. Retrieved from Air pollutant emissions: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-pollutant-emissions.html

Hard Working Trucks. (2017). *2018 Hino 195h diesel hybrid cabover delivers impressive fuel savings*. Retrieved from Hard Working Trucks: https://www.hardworkingtrucks.com/2018-hino-195h-diesel-hybrid-cabover-delivers-impressive-fuel-savings/

Herron, D. (2017). *Energy Density in Battery Packs or Gasoline*. Retrieved from Greentransportation.info: https://greentransportation.info/energy-transportation/energy-density.html

Hubert, C. (n.d.). *GNVERT/GDF Suez Promotes LNG as a Fuel for Heavy Trucks in France by Partnership With Truck Manufacturers.*

ICCT. (2018). *Automation in the long haul: Challenges and Opportunities of Autonomous Heavy-Duty Trucking in the United States.*

IEA. (2018). *Global EV Outlook 2018 - Towards Cross-Modal Electrification.*

IEA. (2018). *Mobility Model.* Retrieved from https://www.iea.org/topics/transport/mobilitymodelpartnership/

J.B. Hunt. (2014). *Natural Gas in Transportation.*

Jerry, T. (2018, December 12).

Lee, D. e. (2018). Life-cycle Implications of Hydrogen Fuel Cell Electric Vehicle Technology for Medium and Heavy-Duty Trucks. *Journal of Power Sources, 393*, 217-229.

Market Snapshot: EVs in Canada – The hidden potential of the electric truck market . (2019). Retrieved from National Energy Board: https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/snpsht/2019/01-01lctrcvhclcnd-eng.html

Mather, J. (2018, August 10). Executive Director, Clean Energy BC. (P. Dehnel, Interviewer)

Montreal Gazette. (2018). *Montreal, Laval team up in Canada's largest order of electric buses*. Retrieved from Montreal Gazette: https://montrealgazette.com/news/local-news/montreal-laval-team-up-in-canadas-largest-order-of-electric-buses

Municipal Advocacy Solutions. (2017). *Comprehensive Municipal Guide to Federal Funding.*

National Energy Board. (2016). *Canada's Energy Future 2016: Energy Supply and Demand Projections to 2040.* Retrieved from National Energy Board: http://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016/index-eng.html

National Energy Board. (2019). Retrieved from Market Snapshot: EVs in Canada – The hidden potential of the electric truck market: https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/snpsht/2019/01-01lctrcvhclcnd-eng.html

National Energy Board. (2019). Market Snapshot: EVs in Canada – The hidden potential of the electric truck market. Retrieved from http://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/snpsht/2019/01-01lctrcvhclcnd-eng.html

National Research Council of the National Academies. (2012). Medium and Heavy Duty Hybrid Vehicles. In *Review of the 21st Century Truck Partnership, Second Report* (pp. 59-77). The National Academies Press. Retrieved from https://www.nap.edu/read/13288/chapter/6#60

Natural Resources Canada. (2009). *Canadian Vehicle Survey - 2009 Summary Report.* Natural Resources Canada.

Natural Resources Canada. (2016, April 28). *Fuel Efficiency Benchmarking in Canada's Trucking Industry*. Retrieved from Natural Resources Canada: https://www.nrcan.gc.ca/energy/efficiency/transportation/commercial-vehicles/reports/7607

Natural Resources Canada. (2018). Retrieved from Electric Charging and Alternative Fuelling Stations Locator: Vehicle Conversion to Natural Gas or Biogas

Natural Resources Canada. (2018). *Diesel Prices - Prices by City*. Retrieved from Natural Resources Canada: https://www.nrcan.gc.ca/energy/fuel-prices/4797

Natural Resources Canada. (2018, September 11). *Energy Sources - Average Retail Prices for Auto Propane in Canada*. Retrieved from Natural Resources Canada: http://www2.nrcan.gc.ca/eneene/sources/pripri/prices_byyear_e.cfm?ProductID=6

Natural Resources Canada. (2018). *Readiness of Producing and Deploying Liquid Drop-In Fuels in Canada*. Retrieved from Natural Resources Canada: https://www.nrcan.gc.ca/energy/transportation/alternative-fuels/resources/21270

NC Clean Energy Technology Center. (2015). *Financing Models: Propane Autogas Vehicles and Infrastructure.*

New Atlas. (2018). *Daimler unveils heavy-duty eCascadia and medium-duty eM2 electric trucks*. Retrieved from New Atlas: https://newatlas.com/daimler-trucks-freightliner-electrics/54946/

New Flyer. (2018). Excelsior CHARGE. Retrieved from https://www.newflyer.com/buses/xcelsior-charge/

Newsweek. (2019, April 25). *Renewable Natural Gas now part of the Low Carbon Fuel Standard* . Retrieved from Newswire: https://www.newswire.ca/news-releases/renewable-natural-gas-now-part-of-the-low-carbon-fuel-standard-891032986.html

Newswire. (2012). *Waste Management First In Ottawa with Natural Gas Fuelled Waste Collection Vehicles* . Retrieved from Newswire: https://www.newswire.ca/news-releases/waste-management-first-in-ottawa-with-natural-gas-fuelled-waste-collection-vehicles-509456441.html

Newswire. (2018). *Loop Energy Fuel Cell Range-Extenders Chosen for FAST TRACK Project*. Retrieved from Newswire: https://www.newswire.ca/news-releases/loop-energy-fuel-cell-range-extenders-chosen-for-fast-track-project-690353781.html

NGT News. (2019, April 28). *TransLink Sourcing RNG for Natural Gas Bus Fleet*. Retrieved from NGT News: https://ngtnews.com/translink-sourcing-rng-for-natural-gas-bus-fleet

NGV Global. (2017). *Canadian City Commits to CNG for Transit Fleet*. Retrieved from NGV Global: https://www.ngvglobal.com/blog/canadian-city-commits-cng-transit-fleet-0714

NGV Global News. (2016). *CNG Buses Exceed Expectations for Kamloops BC*. Retrieved from https://www.ngvglobal.com/blog/cng-buses-exceed-expectations-for-kamloops-bc-0910

OECD. (2016). *The Role of Public Procurement in Low-Carbon Innovation.* Retrieved from https://www.oecd.org/sd-roundtable/papersandpublications/The%20Role%20of%20Public%20Procurement%20in%20Low-carbon%20Innovation.pdf

O'Meara, D. (2016). The Opportunity for Renewable Natural Gas in Canada. Retrieved from http://www.energymag.ca/markets/the-opportunity-for-renewable-natural-gas-in-canada/

Ontario Ministry of Agriculture, Food and Rural Affairs. (2015). Factsheet - Vehicle Conversion to Natural Gas or Biogas. Retrieved from http://www.omafra.gov.on.ca/english/engineer/facts/12-043.htm

Ontario Ministry of Transportation. (2018). *Green Commercial Vehicle Program - 2018-19 Program Guide.* Retrieved from http://www.grants.gov.on.ca/GrantsPortal/en/OntarioGrants/GrantOpportunities/PRDR018055

Ontario Trucking Association. (2011). *Local Truck Routes: A Guide for Municipal Officials.*

Pollution Probe. (2018). *Decarbonizing Transportation in Canada: Building a Foundation for Success.*

Province of BC. (2010). *Community Energy and Emissions Inventory.*

Province of BC. (2018). Retrieved from Provincial Greenhouse Gas Emissions Inventory: https://www2.gov.bc.ca/gov/content/environment/climate-change/data/provincial-inventory

Province of BC. (2018, December 13).

Province of BC. (2018). *Climate Action Legislation*. Retrieved from Province of BC: https://www2.gov.bc.ca/gov/content/environment/climate-change/planning-and-action/legislation

Province of BC. (2018). *Offset Protocol Consultation*. Retrieved from Province of BC: https://www2.gov.bc.ca/gov/content/environment/climate-change/industry/offset-projects/consultation

Province of BC. (n.d.). *Hydrogen Fueling Infrastructure*. Retrieved from Province of BC: https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/clean-transportation-policies-programs/clean-energy-vehicle-program/hydrogen-fuelling

Province of British Columbia. (2018). Clean Energy Act - Greenhouse Gas Reduction (Clean Energy) Regulation. Retrieved from http://www.bclaws.ca/civix/document/id/complete/statreg/102_2012

Province of British Columbia. (2018). *Intentions Paper Clean Transportation: Building a clean growth future for B.C.,.* Retrieved from https://engage.gov.bc.ca/app/uploads/sites/391/2018/07/MoE-IntentionsPaper-Transportation.pdf

Reeve Consulting. (2017). *The Annual Report on the State of Sustainable Public Procurement in Canada - 2017 Trends & Best Practices Case Studies.* Retrieved from https://reeveconsulting.files.wordpress.com/2018/02/2017-state-of-the-nation-report-on-sustainable-public-purchasing-in-canada.pdf

Renewable Cities. (2018). *Mapping Enabling Policies for Vancouver's 100% Renewable Energy Strategy*. Retrieved from Renewable Cities: https://www.renewablecities.ca/dialogues-projects/mapping-enabling-policies-for-vancouvers-100-renewable-energy-strategy

Renewable Cities. (n.d.). *B.C. Local Government Renewable Natural Gas Roadmap*. Retrieved from Renewable Cities: https://www.renewablecities.ca/dialogues-projects/bc-local-government-renewable-natural-gas-roadmap

Reuters. (2018). *Daimler fights Tesla, VW with new electric big rig truck*. Retrieved from Reuters: https://www.reuters.com/article/us-daimler-trucks/daimler-fights-tesla-vw-with-new-electric-big-rig-truck-idUSKCN1J22A5

Roland Berger. (2017). *Fuel Cells and Hydrogen Applications for Regions and Cities Vol 1.*

Rubber & Plastics News. (2018, April 23). *Surge in business is a boon for commercial vehicle industry*. Retrieved from Rubber & Plastics News: http://www.rubbernews.com/article/20180423/NEWS/180429986/surge-in-business-is-a-boon-for-commercial-vehicle-industry

Scott, W. (2017). *Low Carbon Fuel Standards in Canada.* Smart Prosperity Institute.

SMMT. (2016). *New long-haul CNG truck a world first*. Retrieved from SMMT: https://www.smmt.co.uk/2016/06/new-long-haul-cng-truck-a-world-first/

State of Delaware. (2018). *Heavy-Duty Vehicle Rebate Program*. Retrieved from State of Delaware: https://dnrec.alpha.delaware.gov/energy-climate/clean-transportation/heavy-duty-vehicle-rebates/

Statistics Canada - The Daily. (2017, June 29). Vehicle Registrations, 2016. Retrieved from https://www150.statcan.gc.ca/n1/daily-quotidien/170629/dq170629d-eng.pdf

Statistics Canada. (2016). Vehicle Registrations, 2015. Canada. Retrieved from https://www150.statcan.gc.ca/n1/daily-quotidien/160628/dq160628b-eng.htm

Statistics Canada. (2019). *Monthly average retail prices for gasoline and fuel oil, by geography*. Retrieved from Statistics Canada: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1810000101

The National Academies of Science, Engineering, and Medicine. (2017). *Decarbonizing Transport for a Sustainable Future - Mitigating Impacts of the Cnanging Climate.*

The Pembina Institute. (2017). *The State of Freight.* Retrieved from http://www.pembina.org/reports/state-of-freight-report.pdf

The Star Vancouver. (2018). *B.C. company poised to power more California buses with zero-emission engines*. Retrieved from The Star Vancouver: https://www.thestar.com/vancouver/2018/07/18/bc-company-poised-to-power-more-california-buses-with-zero-emission-engines.html

Today's Trucking. (2017). *Hyliion is turning diesel engines into hybrids*. Retrieved from Todaystrucking.com: https://www.todaystrucking.com/hyliion-is-turning-diesel-engines-into-hybrids/

Toronto Star. (2017, November 29). *Loblaw pre-orders 25 of Tesla's new all-electric trucks for undisclosed price* . Retrieved from Toronto Star: https://www.thestar.com/business/2017/11/17/loblaw-pre-orders-25-of-teslas-new-all-electric-trucks-for-undisclosed-price.html

Toronto Transit Commission. (2017). *2018-2040 Green Bus Technology Plan.* Toronto: TTC.

Translink. (2016). *Keeping Metro Vancouver Moving - Truck Route Reference Guide.* Retrieved from https://www.translink.ca/~/media/Documents/plans_and_projects/roads_bridges/Truck%20Route%20Reference%20Guide.ashx

Transport Canada. (2018). *Programs.*

Truckinginfo. (2017, November 29). *Truckinginfo*. Retrieved from Electric, Hybrid Trucks to Exceed 1.6 Million Units by 2027: https://www.truckinginfo.com/143229/electric-hybrid-trucks-to-exceed-1-6-million-units-by-2027

Truckinginfo. (2017). *What's Hot in Medium-Duty for 2018*. Retrieved from Trucking Info: https://www.truckinginfo.com/157750/whats-hot-in-medium-duty-for-2018

U.S. DOE. (2018, April). *Fuel Prices.* Retrieved from Alternative Fuels Data Center: https://www.afdc.energy.gov/fuels/prices.html

U.S. DOE. (2018). *Hydrogen and Fuel Cells Update.* U.S. DOE. Retrieved from https://www.energy.gov/sites/prod/files/2018/02/f49/fcto_h2_fc_update_satyapal_transp_research_board_2018.pdf

UPS. (2015). Retrieved from UPS Deploys 18 New Zero Emission Electric Trucks In Texas: https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1446039616630-395

Vancouver Electric Vehicle Association. (2003). *Well-to-Wheel Energy Usage Comparisons for Various Motive Technologies*. Retrieved from Vancouver Electric Vehicle Association: http://legacy.veva.ca/wtw/index.php

Victoria Transport Policy Institute. (2018). *Freight Transport Management - Increasing Commercial Vehicle Transport Efficiency*. Retrieved from Victoria Transport Policy Institute: http://www.vtpi.org/tdm/tdm16.htm

WLPGA. (2017). *LPG for Heavy Duty Engines - Buses, Trucks, Marine and Other Applications.*

[i] (Province of BC, 2018)

[ii] (Government of Canada, 2019)

[iii] (Community Energy Association, 2011)

[iv] (Truckinginfo, 2017)

[v] (Toronto Star, 2017)

[vi] (Electrek, 2019)

[vii] (Canadian Natural Gas Vehicle Alliance, 2015)

[viii] (Canadian Biogas Association, n.d.)

[ix] (National Energy Board, 2016)

[x] (Natural Resources Canada, 2018)

[xi] (E3Fleet, 2018)

[xii] (National Energy Board, 2019)

[xiii] (Deloitte, 2016)

[xiv] (Cummins Westport, 2018)

[xv] (Herron, 2017)

[xvi] (Jerry, 2018)

[xvii] (Scott, 2017)

[xviii] (Natural Resources Canada, 2018)

[xix] (Province of BC, 2018).

[xx] (Today's Trucking, 2017)

[xxi] (CTV News, 2017)

[xxii] (Vancouver Electric Vehicle Association, 2003)

[xxiii] (O'Meara, 2016)

[xxiv] (CivicinfoBC, 2019)

[xxv] (Renewable Cities, n.d.)

[xxvi] (City of Vancouver, 2018)

[xxvii] (Carbon Neutral Kootenays, 2012)

[xxviii] (BC Laws, 2018)

[xxix] (Reeve Consulting, 2017)

[xxx] (Montreal Gazette, 2018)

[xxxi] (Newswire, 2012)

[xxxii] (Newswire, 2018)

[xxxiii] (FortisBC, 2012)

[xxxiv] (Community Energy Association, 2018)

[xxxv] (NGV Global News, 2016)

[xxxvi] (Golder Associates, 2008)

[xxxvii] (Province of BC, 2018)

[xxxviii] (Province of BC, 2018)

[xxxix] (Victoria Transport Policy Institute, 2018)

[xl] (Translink, 2016)

[xli] (Bate, 2018)

[xlii] (FortisBC, 2018)

[xliii] (Canadian Linen, 2016)

[xliv] (Coldstar Solutions, 2014)

[xlv] (Autotrader, 2018)

[xlvi] (CTV News, 2017)

[xlvii] (City of Vancouver, 2018)

[xlviii] (Truckinginfo, 2017)

[xlix] (New Atlas, 2018)

[l] (Reuters, 2018)

[li] (National Research Council of the National Academies, 2012)

[lii] (Bachmann, 2014)

[liii] (Hard Working Trucks, 2017)

[liv] (CNGVA, 2018)

[lv] (Province of British Columbia, 2018)

[lvi] (Newsweek, 2019)

[lvii] (Lee, 2018)

[lviii] (Roland Berger, 2017)

[lix] (Canada Cartage, 2017)

[lx] (Forbes, 2018)

[lxi] (SMMT, 2016)

[lxii] (Province of British Columbia, 2018)

[lxiii] (U.S. DOE, 2018)

[lxiv] (Boston, 2018)

[lxv] (New Flyer, 2018)

[lxvi] (The Star Vancouver, 2018)

[lxvii] (Toronto Transit Commission, 2017)

[lxviii] (Community Energy Association, 2018)

[lxix] (CBC News, 2014)

[lxx] (Gerber, n.d.)

[lxxi] (NGT News, 2019)

[lxxii] (Environment and Climate Change Canada, 2018)

[lxxiii] (Natural Resources Canada, 2009)

[lxxiv] (IEA, 2018)