Appendix C

ZERO EMISSION VEHICLE FLEET ASSESSMENT

PREPARED FOR

WHISTLER | Resort Municipality of Whistler

RESORT MUNICIPALITY OF WHISTLER

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v1.0

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EXECUTIVE SUMMARY

The Resort Municipality of Whistler (RMOW) has committed to reduce its greenhouse gas (GHG) emissions. As part of that initiative the organization has commissioned ChargeFWD to conduct a fleet assessment to provide a recommended framework for how the fleet can transition to zero emission vehicles (ZEVs) over the next decade. Fleets throughout British Columbia have made progress toward electrifying and have set ambitious targets for reducing GHG emissions derived from transportation.

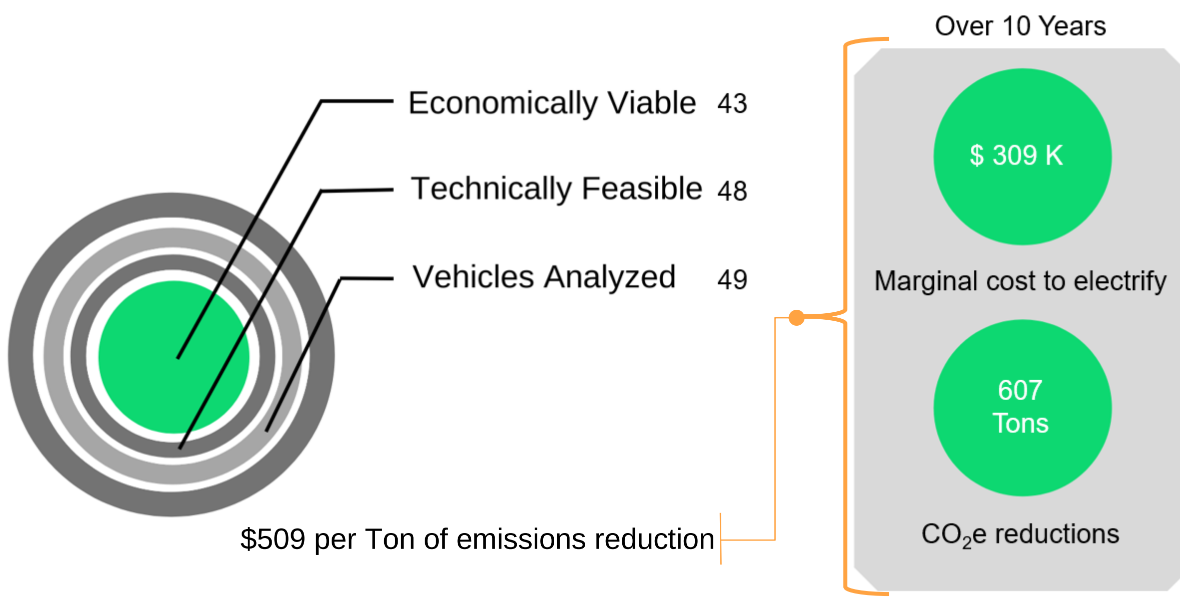

Figure 1 – Opportunity presented by ZEV adoption based on recommended Roadmap (Scenario 4)

The case for cost effective electrification of nearly all vehicle procurements for the RMOW looks favorable over the timeline extending through 2032. This is primarily for three reasons.

First, 50-60% of an electric vehicle's (EV) cost is derived from the battery pack. As the cost of manufacturing battery packs continues to fall, it is expected that ZEVs will reach price parity with internal combustion engine (ICE) vehicles. In addition to downward pressure on ZEV prices, stricter fuel standards and taxes on emissions will also make fossil fuel purchases more expensive further increasing the competitiveness of ZEVs in years to come.

Second, automakers are racing to gain market share as the importance of the ZEV market becomes apparent to the future of the auto industry. Therefore, automakers are investing billions to bring new ZEVs models to market and retooling their factories and supply chains. As of 2022 low volumes of ZEV models such as work trucks and vans are being delivered to fleet operators.

And third, the widespread adoption of industry standards for charging infrastructure is accelerating investment in charging infrastructure deployments. Infrastructure investments can now be made with a high degree of certainly that costs will remain stable, deployments will be utilized, and infrastructure is future proofed.

The factors that limit widespread ZEV adoption in fleets today is the high cost of batteries, lack of charging infrastructure and limited production capacity. Today ZEVs are available for short haul use cases, however, as the vehicles are only being produced in low volume, they are cost prohibitive. For example, there are electric fire, refuse, and last mile-delivery trucks available for purchase today but with the cost of the vehicles in the $200k -$1M range its uncommon to realise an adequate return on investment for the purchases.

Price parity is the point at which the purchase price of an ICE and ZEV are the same. With battery prices reducing, price parity is predicted to occur within three years, at which time production of ICE vehicles can reasonably be expected to become financially problematic for automakers. The probable outcome is that when price parity is achieved, it will no longer make sense for automakers to produce ICE vehicles, and a major inflection point will occur, resulting in rapid acceleration in the adoption of ZEVs.

The initial purchase price of ZEVs will be driven down by increased competition and economies of scale in the years to come. As such the lifetime total cost of ownership of ZEVs will be competitive with internal combustion engine (ICE) vehicles. An increasing number of ZEVs on the road will require a similar increase in electric vehicle (EV) charging infrastructure. By leveraging existing rebates programs through the provincial CleanBC Go Electric and federal NRCAN programs there are options for the adoption for EV charging infrastructure. The capital investment in ZEVs and infrastructure will be significant. And by 2032 RMOW's fleet could require as much as **134 MWh** of electricity to support its adoption.

The next step is to perform a ZEV infrastructure assessment. This analysis would review the existing electrical infrastructure at the fleet depot and determine the required charging infrastructure to support the transition to ZEVs. RMOW is well positioned to cement its leadership position in the decarbonization of its fleet operations.

INTRODUCTION

Residents, businesses, and governments at all levels in British Columbia are moving forward in a largescale effort to reduce the impact of carbon emitting vehicles. The use of fossil fuels in transportation is the largest source of greenhouse gas emissions in BC and a significant source of other air pollutants, such as particulate matter and nitrogen oxides. Increasing the adoption of zero emission vehicles (ZEVs) is a critical step in meeting the climate and public health goals encapsulated in the province's legislated emission reduction targets.

In Canada, British Columbia is a leader in transportation electrification and has the largest passenger electric vehicle (EV) market in Canada. BC also has the largest number of registered EVs and EVs registered per capita. The province has made significant effort to be seen as a high priority market for zero emission vehicle automakers.

Passenger EV adoption has increased significantly in BC. The result is an estimated 216,000 tonnes in emission reductions per year[1].

Increasing sales coincides with expanded EV range resulting from significant battery cost declines seen between 2010 and 2018[2]. This trend is expected to continue with Bloomberg New Energy Finance predicting that the average price per kilowatt-hour of battery capacity will fall below $100 per kilowatt-hour by 2024.

EV market growth in BC has been accompanied by a large expansion of the EV models offered for sale. BC offered 38 EV models for sale as of July 2022, 18 more than were offered in 2019. Nationwide, more than 62 new EVs are expected to reach the market by the end of 2022 including vehicles like pickup trucks. EV model offerings will be supported by the BC ZEV mandate which requires automakers to meet an escalating annual percentage of new light-duty ZEV sales and leases, reaching: 10% of light-duty vehicle sales by 2025, 30% by 2030 and 100% by 2040.

Public fleet operators in BC have an opportunity to lead electrification efforts and serve as an example for private fleets and individual drivers. The benefits of ZEVs are operational cost savings

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[1] "B.C. Reports Record Numbers of EV Sales," April 2021. https://www.guideautoweb.com/en/articles/59409/b-c.-reports-record-numbers-of-ev-sales/#:~:text=British%20Columbia%20had%2054%2C469%20registered,a%20rapid%20pace%20in%202021

[2] Atlas EV Hub, "Automakers Dashboard," April 2021. https://www.atlasevhub.com/materials/automakers-dashboard/

and air quality benefits associated. BC has already taken steps to implement policy requiring fleets across the province to transition to ZEVs.

To advance progress on fleet electrification, the RMOW directed ChargeFWD to complete a comprehensive study to determine the costs and benefits of electrifying the fleet. The assessment team sought to provide fleet managers with a report that encompassed a comprehensive, vehicle-specific electrification cost estimate for today and in the future and actionable information on how to efficiently move forward with fleet electrification.

ABOUT THIS FLEET ASSESSMENT

This fleet assessment is a vehicle-by-vehicle assessment of the electrification potential for the RMOW's fleet vehicles. In-scope of this assessment are 49 vehicles which range from light-duty (Class 1B) to medium-duty (Class 2H) (Appendix B).

This report is broken out into nine sections.

Section 1: To provide context to frame this report it is important that the reader has a fundamental understanding of what an ZEV is and how they are different from ICE vehicles.

Section 2: A review of the existing fleet duty cycle is summarized in the second section of the report to give the reader an understanding of what type of vehicles the fleet is comprised of and the operational requirements.

Section 3: The fleet replacement timeline is graphed to demonstrate the time scale of the current fleet's vehicle replacement cycle.

Section 4: An overview and recommendations for EV products is detailed in the fourth section of the report to provide the reader with a picture of what is currently available on the market in terms of ZEV replacement options.

Section 5: Expanding on the fundamentals section the overview and recommendations for EV charging infrastructure are detailed in fifth section of the report.

Section 6: The Roadmap of phased approach to EV adoption details four scenarios and how ZEV can be aggressively adopted into the fleet. The roadmap details the timeline for vehicle and supporting infrastructure acquisitions.

Section 7: The Energy and GHG impacts of EV adoption expands on the scenario modeled in the roadmap and provides a forecast of the fleet's future energy demands and emissions.

Section 8: The Cost Benefit Analysis takes the information from the total cost of ownership and the emissions reductions analysis and graphs it as a cost benefit analysis which measures the cost in dollars and benefit in CO_2e emissions reduction.

Section 9: The reports summary and next steps are detailed with a focus on establishing an understanding of key takeaways, next steps, and opportunities for additional research.

SECTION 1: FUNDAMENTALS

An electric vehicle (EV) is any vehicle with an electric drivetrain. The electric drivetrain is what differentiates an electric vehicle from a conventional fossil- fueled vehicle where the drivetrain is mechanical. Electric vehicles may be either fully electric, referred to as battery electric vehicles (BEVs); or a combination of electric and gasoline powered, identified as plug-in hybrid electric vehicles (PHEVs). Both require recharging of the battery via electric vehicle charging equipment.

Electric vehicle charging equipment, referred to as electric vehicle supply equipment (EVSE), is classified in the following major categories:

Level	Description
1	15 or 20A, 120V 1φ power outlet
2	40A-100A, 208V 1φ or 240V 1φ EVSE
3	30A or higher, 480V 3φ EVSE.

Table 1 – Description of EV Charging levels

Fast, reliable, and safe charging options are required for electric vehicles. Not too long ago there were limited scenarios for electric vehicles to achieve all three of these requirements. Many car owners and fleet managers would not consider electric vehicles as a viable option unless there were safe, reliable charging facilities in predictable ranges and locations. In contrast, investors of charging infrastructure typically expect quick and regular income after EV infrastructure installations. Today the gap between the availability of safe and reliable EV chargers and users is lessening. It could be noted that this trend mirrors the roll out of fossil fueled vehicles and gas stations from around a century ago.

Level 2 offers the best value for money

Level 1	Level 2	Low Power DCFC	DCFC	High Power DCFC
Note: you'll need your own cable to plug in to the wall for Level 1	J1772 connector	SAE Combo (CCS), CHAdeMO, Tesla	SAE Combo (CCS), CHAdeMO, Tesla	SAE Combo (CCS), CHAdeMO, Tesla
1.4kW	1.4-19.2kW	20-35kW	50-100kW	100kW+
$300 - $2K	$3K-$12K	$30K	$90K	$100K+

Table 2 – Power output and price range of charging stations

Level 1: charging (8 km/hr) utilizes a regular 15A or 20A power outlet. While Level 1 may be adequate for some vehicles, or some days of driving, it is insufficient for those times when greater distances are traveled, and greater amounts of electricity are necessary.

Level 2: charging (25 km/hr) stations are essentially power delivery devices, like a switch, with electronics for communications with the vehicle to manage the charging process. For Level 2 charging the actual "charger" is onboard the vehicle and includes a rectifier to supply direct current (DC) to the battery. This is different to DCFC, which incorporate a rectifier that bypasses the onboard charger. For this reason, the charging power received from a Level 2 charger is limited by the onboard charger of the vehicle, which ranges from 3.3kW to 19.2kW, depending on vehicle make. Most Level 2 chargers are designed to operate on a dedicated circuit, without interruption from adjacent chargers.

Level 3 (DCFC): charging (>100km/hr) is typically not financially viable in most business applications due to its high costs. Level 3 charging is referred to as Direct Current Fast Charging (DCFC). Level 3 charging is now available as standard for most BEVs in North America, with the connector known as a SAE Combo (CCS1). The CHAdeMO connector is an alternative DCFC charging standard which was mostly used by Japanese auto makers. Tesla vehicles can also use an adapter to make use of the CHAdeMO connector.

> With regards to Level 3 DC fast charging the SAE Combo (CCS1) connector has become the standard in North America.

However, most Tesla drivers opt to use Tesla's supercharger network which makes use of Tesla's proprietary connector. Level 3 (DCFC) chargers are typically provided as a part of extensive highway networks for long distance travel. The major DCFC networks in B.C. include Tesla, Electrify Canada, Petro-Canada, Canadian Tire, and BC Hydro. Motivation for the installations can predominantly be attributed to greenhouse gas (GHG) emissions reduction and operational requirements, i.e., financial return was not the motivating factor.

SECTION 2: FLEET AND DUTY CYCLE

Duty cycle matters when going electric. A duty cycle is the route a vehicle operates on a regular basis. The duty cycle analysis determines the suitability of ZEV replacements. The three key indicators that determine whether a duty cycle is suitable for electrification is the *average* and *maximum daily Vehicle Kilometers Traveled (VKT)* and the overnight *dwell time* at the depot. The daily average and maximum VKT must fall within the range constraint of the ZEV replacement. The overnight dwell time determines the power rate requirement for any supporting charging infrastructure.

RMOW's fleet vehicle utilization varies for each vehicle.

Body Class	Count	Ave. daily VKT	Ave. Max daily VKT
Pickup	29	46	155
Hatchback	6	43	225
SUV	9	44	206
Van	5	25	138

Table 3 – Vehicle Utilization

Each vehicle's duty cycle is unique but for the purposes of this report they have been grouped by body class and their data has been averaged. From the data provided by the RMOW a fleet list was summarised and estimated average duty cycle calculations performed. To complete the analysis additional data sources such as NRCan's fuel consumption data[3] and Atlas Policy's DRVE tool[4] was utilized as a foundation for our results.

For an example of a duty cycle, a parcel delivery van may leave the depot at 6am, travel a 50 km route performing pickups and deliveries and then return to base at 6pm, where the vehicle is parked (dwell-time) for 12 hours until the next shift. An example of a duty cycle that is not technically feasible to electrify would be that of a dump truck performing snow removal duties during a snowstorm. The duty of cycle of such a vehicle could be 24 hours of continuous use for

[3] Fuel consumption ratings, May 2021
https://open.canada.ca/data/en/dataset/98f1a129-f628-4ce4-b24d-6f16bf24dd64

[4] Dashboard for Rapid Vehicle Electrification (DRVE), May 2021
https://www.atlasevhub.com/materials/drve/

several days in a row. The dump truck would not have a large enough charging window to perform these duties effectively, nor would the battery have enough capacity to perform the required tasks. Below is an example of a duty cycle review of one of the organizations fleet vehicles.

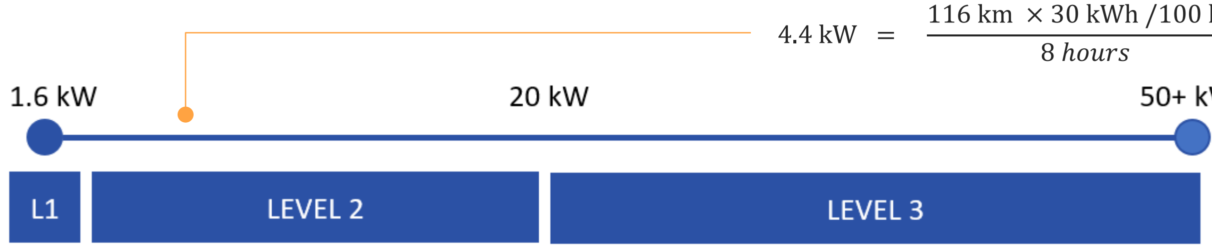
Current Vehicle 2013 Ford F-150	
Est. Average Daily VKT	42 km
Est. Maximum Daily VKT	116 km
Est. Overnight Dwell Time	8 hrs
Replacement Vehicle Ford F150 Lightning	
Consumption	30 kWh / 100 km
Range	380 km

Table 4 – Duty Cycle example

Minimum range requirement of the ZEV replacement for unit V430 (2013 Ford F-150) duty cycle profile is between 42 – 116 km. The minimum power requirement for charging infrastructure can be calculated using these figures.

$$\text{Minimum power requirement for charging infrastructure} = \frac{\text{Max. Daily VKT} \times \text{Consumption}}{\textit{Dwell Time}}$$

$$4.4\ \text{kW} = \frac{116\ \text{km} \times 30\ \text{kWh}/100\ \text{km}}{8\ \textit{hours}}$$



From these calculations we can see that the duty cycle of vehicle V430 can be performed by a F150 lightning BEV and that the minimum required charging infrastructure to support this vehicle would be a level 2 charging station.

SECTION 3: FLEET REPLACEMENT TIMELINE

The average age of the vehicles in scope is **7 years**, and the average expected life of the units is **12 years**. Fleets often target a **12-year** vehicle replacement policy for light duty vehicles, however, due to delay in availability and delivery of ZEVS in the market, our recommendation is to aim for a replacement within **15 years or 320,000 km travelled in lifetime**, whichever comes first in-order to get allow time for ZEV to be delivered into the fleet.

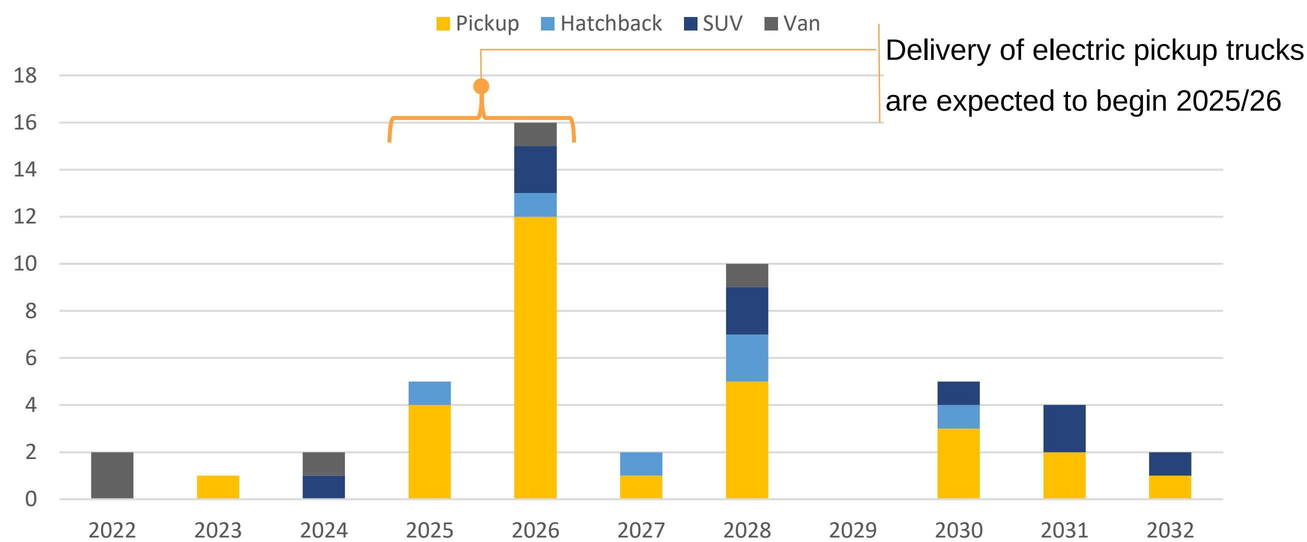


Figure 2 – Recommended replacement schedule for existing fleet, based upon a 15-year vehicle lifecycle

The RMOW's fleet is mostly comprised of a combination of Light Duty and M&HD vehicles. The **average daily kilometers** travel by these vehicles is **43 km** and **average annual kilometers** travelled is **9,879 km**. All vehicles are due for replacement within 10 years.

SECTION 4: ZEV MARKET OVERVIEW

As of April 2022, the choice of ZEVs in BC limited is to 64 light-duty vehicles[5]. Of this only 24 models are suitable vehicles for fleet applications. Automakers currently prioritize their business models towards retail customers of high-end passenger vehicles that value having the latest technology rather than fiscally responsible Fleet Managers. For these buyers a vehicle purchase is primarily driven by emotion rather than total cost of ownership.

The research and development of electric vehicles is expensive; therefore, automakers are prioritizing their most profitable customers and models first. However, as the high-end passenger vehicle market gets saturated, automakers will expand their product lines into untapped markets such as ZEVs specifically designed for fleet use. High-end luxury passenger vehicles from Tesla, Mercedes, Audi, and Porsche are available on the market already. An increasing number of commuter passenger vehicles, especially in the popular crossover segment are also now available.

In 2022 expected deliveries of the first all-electric pick-up trucks are to be made. The City of Richmond will be one of the first organizations to adopt the Ford F-150 Lighting BEV into its municipal fleet. In the next few years, we expect commercial vans to be produced in large quantities and production of special purpose medium and heavy-duty vehicles to follow.

Figure 3 – F-150 Lighting Photo Credit: Ford.ca

[5] List of ZEV available in BC, July 2021 http://www.emotivebc.ca/wp-content/uploads/2020/09/Electric-Vehicles-in-BC.pdf

ZEV Delivery Framework

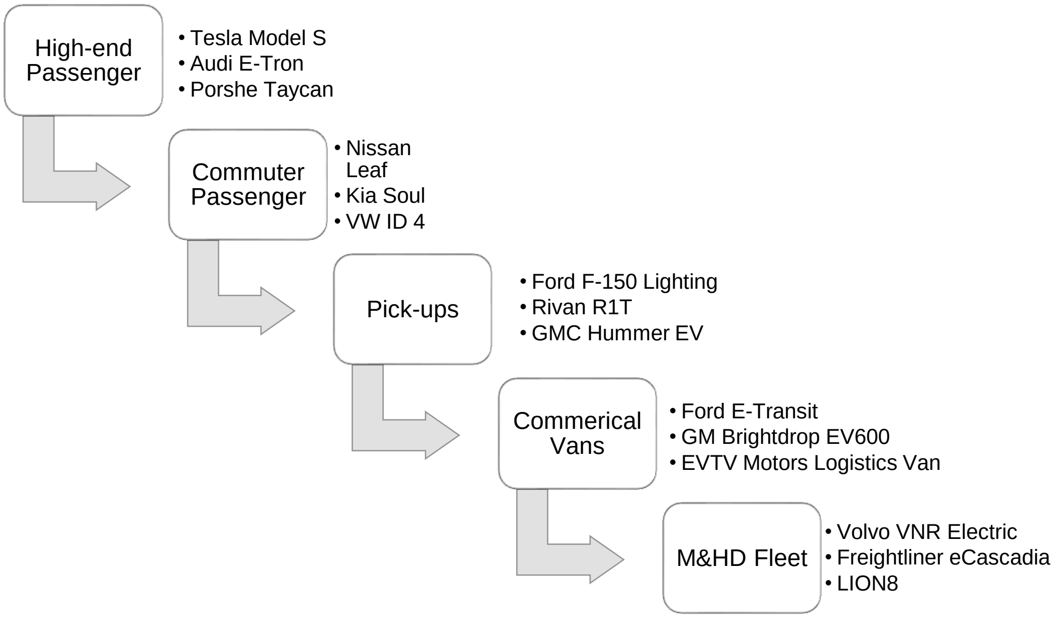


Figure 4 – ZEV delivery framework

This framework is intended to provide a general idea of how automakers will prioritize their ZEV products. There are exceptions to this framework. In the fleet segment one of the most notable exceptions are the converted vehicle segment. Specialist vehicle converters such as Motiv[6], Lightning Systems[7], XL Fleet[8] and Phoenix Motorcars[9] are taking common ICE vehicle chassis such as the Ford transit or F-450 and replacing the mechanical drivetrain with an electric or hybrid drivetrain. These conversions are often only performed in low volumes and are therefore not competitive on price; however, they massively expand the availability of BEVs. In the M&HD segment there are various low volume original equipment manufacturers (OEMs) that offer vehicles in BC such as Electra Meccanica[10], BYD[11], EVT motors[12], Lion Electric[13], and Proterra[14]. A great resource to discover these vehicles is the CleanBC Go Electric Speciality Use Vehicle Incentive (SUVI)[15] website. For a complete list of vehicles in this assessed in our fleet assessment model please seen the appendix A.

[6] https://www.motivps.com/
[7] https://lightningemotors.com/
[8] https://xlfleet.com/
[9] https://www.phoenixmotorcars.com/
[10] https://electrameccanica.com/
[11] https://en.byd.com/
[12] https://evtvusa.com/
[13] https://thelionelectric.com/en
[14] https://www.proterra.com/
[15] https://www.suvibc.ca/eligible-vehicles?category=On road Medium- and Heavy-Duty

SECTION 5: EV CHARGING INFRASTRUCTURE

The coming decade will see the most change the fleet management sector has seen in a century. Electrification, automation, and connected/ shared mobility are three innovations that are on track to disrupt the current way transportation and logistics services are performed. While it is impossible to predict the future, it is best practice to forecast where the industry is going, to be as prepared as possible.

Going forward, fleet managers will have to work much closer with energy and facility managers to successfully deploy EV charging infrastructure.

The traditional goal of an energy manger is to conserve energy. For fleet electrification projects to be successful, energy managers will have to prioritize low carbon fuels and energy sources.

The facility managers role regarding fleet electrification will be to supply, install, own, and maintain charging equipment. Fleet managers need to provide clear guidance to these departments on best practices, their requirements, and expectations.

The role of a fleet manager will undergo change as well. Fewer scheduled and unscheduled vehicle repairs are to be expected with ZEV fleets, however, more time managing charging is expected. Forecasting range requirements of the next days operation will be vital to ensuring all vehicle are able to perform their duty cycles.

Although rolling out ZEV infrastructure is a large capital expense; savings can be achieved when installing ZEV infrastructure by effective planning and limiting rework. Financial support is currently available to fleet operators in the form of rebates for electrical modifications and charging infrastructure. Most fleet facilities can support some adoption of ZEVs without major retrofits. However, high levels of ZEV adoption often require major electrical modifications or energy management systems.

There are three best practices to keep charging infrastructure and electricity demand costs to a minimum:

1. "Make Ready" the facility with roughed in electrical modifications with enough capacity for the future fleet and install the charging stations modularly as and when are required.
2. Charge the vehicles as slow as possible during off peak hours.
3. If space allows place charging stations so that multiple stalls can be serviced from the same station.

Before fully understanding the costs, fleet managers and EV drivers might initially seek the fastest charging available (i.e. level 3 aka DCFC), as this is comparable with the experience of fueling an ICE vehicle. After analyzing the vehicles energy requirement, charging window and cost of infrastructure, fleet managers most often conclude that networked level 2 charging stations provide the best balance of convenience and value for money. Networked charging stations provide the ability to set permissions (who is allowed to charge) and can help to monitor and optimize electrical usage, i.e., energy consumption can be programmed to occur during off-peak hours.

Level 2 charging stations fall into three categories, non-networked, closed network, and open network.

1. **Non-networked** stations as the name suggests have no smart features as they are not connected to a charging station management platform. Non-networked stations are often lower cost than networked station but lack the features that connectivity can provide.
2. **Closed network** charging stations are networked charging stations where the hardware is designed to operate only on the manufacturers network. The manufactures would design the hardware (the charging station) and the software (the charging station management system) in house. This can lead to stranded assets if the manufacturer either goes out of business or chooses not to continue to support the station.
3. **Open network** is the use of the Open Charge Point protocol (OCPP). For open networked charging stations there are various reputable hardware vendors to choose from such as ABB, Delta, Lite-on, Siemens and Enel X. For the software there is a limited but growing number of providers. In Canada SWTCH and ChargeLab are two established charging station management platforms.

SECTION 6: ROADMAP TO ZEV ADOPTION

This section is divided into two work streams. One, ZEV replacements, and two, EVSE deployments to support ZEVs.

ZEV REPLACEMENTS

ChargeFWD has developed a spreadsheet model to estimate and compare financial performance and GHG emissions of different scenarios. The report summarizes the outputs of this model. The model is available to the RMOW to use and refine their fleet planning over time. The scenarios that were analyzed for this report include:

- ***Scenario 1***: Baseline/Like for Like Replacement
- ***Scenario 2***: Prioritize GHG Emission Reductions
- ***Scenario 3***: Prioritize Financial Case)
- ***Scenario 4:*** Balanced (Summarized in Appendix B)

It is best practice to immediately assign ZEVs to operations that consume the most fuel or have the highest vehicle utilization. The vehicle that has been replaced by a ZEV could also be re-assigned to an operation where less fuel will be consumed. Cascading these changes through the fleet will allow for the decommissioning of the least efficient vehicles in the fleet and maximum utilization of the most efficient vehicles.

Figure 5 – Ford E-Transit Photo Credit: Ford.ca

For example, Unit V455 2014 Toyota RAV4 travels an estimated 43,210 km annually would be an ideal target for electrification as it is one of the highest utilized vehicles in the fleet. However, since this vehicle isn't due for replacement until 2026, it would make sense to assign any new ZEV SUV to this duty cycle resulting in the 2014 Toyota RAV4, being available to replace any older decommissioned vehicles. For example, V414 a 2012 Toyota RAV4 which is due for

TCO% premium example: if an ICE vehicle's TCO is $100,000 over 7 years, and a ZEV's TCO is $200,000 over the same period, then the TCO% Premium will be 100%.

replacement in 2024. And for the time being the 2014 Toyota RAV4 could be re-assigned for the operations previously performed by the 2012 Toyota RAV4 until it is due for replacement in 2026.

Place the new ZEVs on the most utilized duty cycles, even if the vehicle currently performing that duty cycle isn't due for replacement yet. The ICE vehicles with remaining useful life can then be reassigned to replace older vehicles being decommissioned from the fleet.

Figure 6 – Ford E-Transit Body Configurations

Often ZEV enthusiasts will promote the lower total cost of ownership of electric vehicles, claiming that the lower operational costs offset the higher initial purchase price. In our analysis this has not been the case for most municipal fleets, as total vehicle kilometres travelled tend to be low when compared to non-municipal fleets. For ZEVs to make economic sense they should be highly utilized. The ideal scenario for a ZEV adoption is a duty cycle between 60km to 200km of daily vehicle kilometers traveled. In this range the savings from reduced fuel and maintenance costs outweigh the higher initial purchase price of the ZEV; making the purchase economically viable, while a daily range of 200km is technically achievable for ZEVs on the market today. As the price parity between ICE and ZEVs is achieved the lower bound of the 60km to 200km range will reduce to zero km. If there is no cost difference between the purchase price of an ICE or ZEVs, then naturally the ZEV will be the most cost competitive option.

Figure 7 illustrates typical TCO for some the representative ICE and ZEV alternatives.

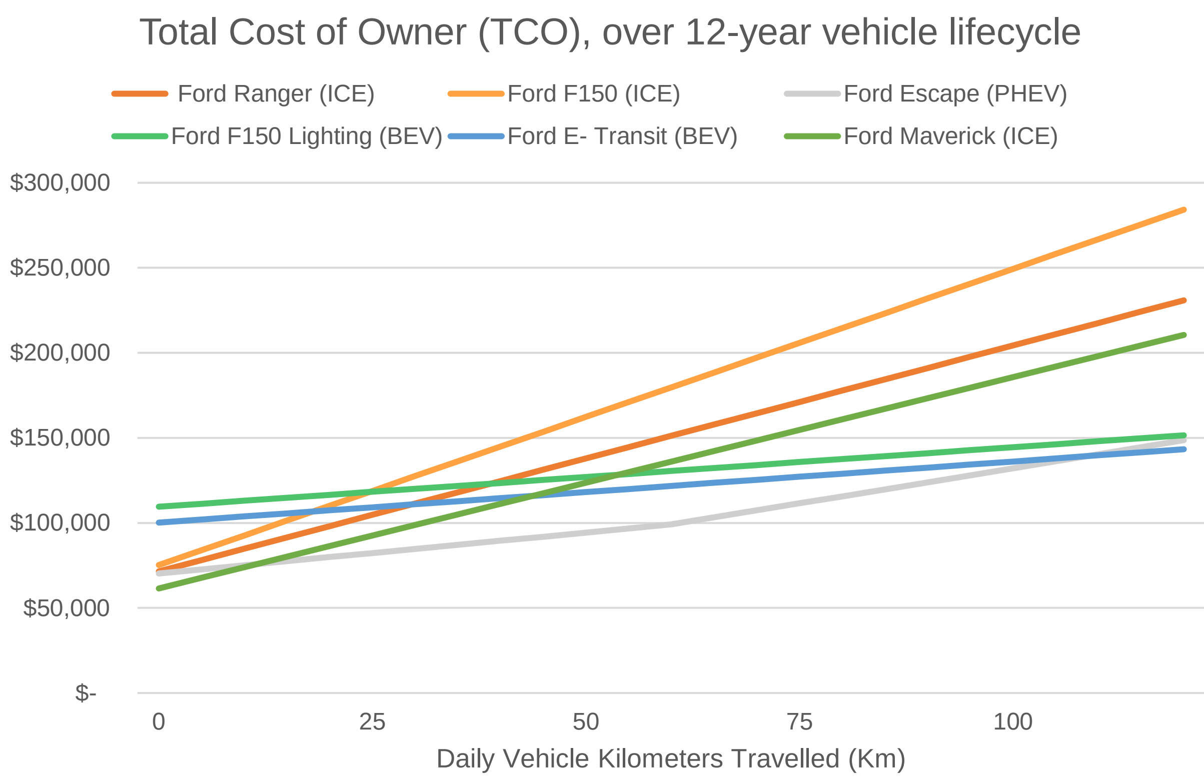


Figure 7 – Total cost of ownership (TCO) for six typical vehicles

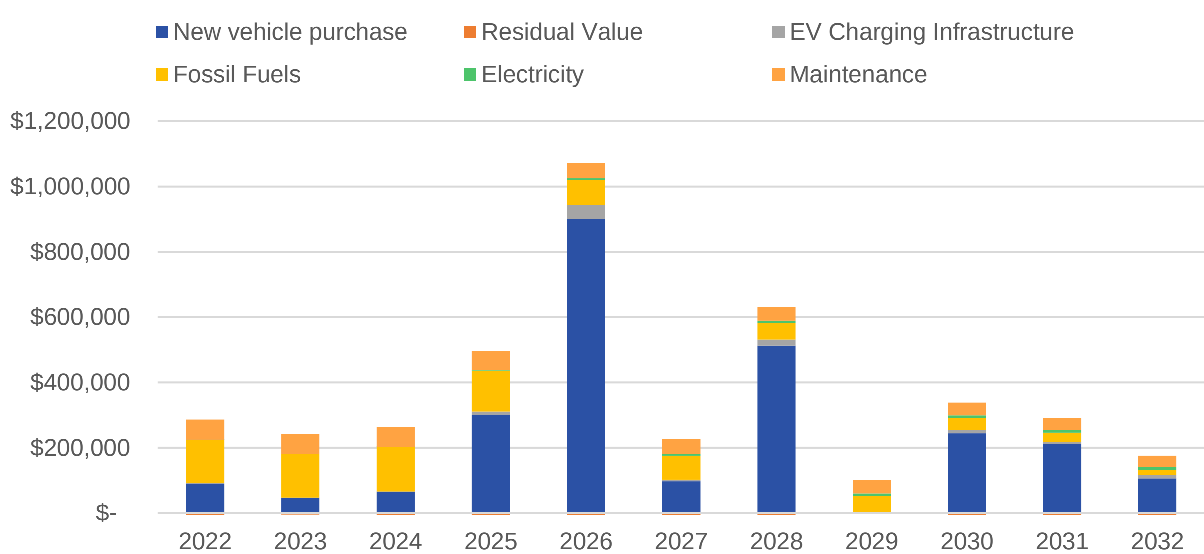


Figure 8 – Scenario 4 cost by year a category

Build-out of battery mega factories (>1GWh), 2015-2020[16]

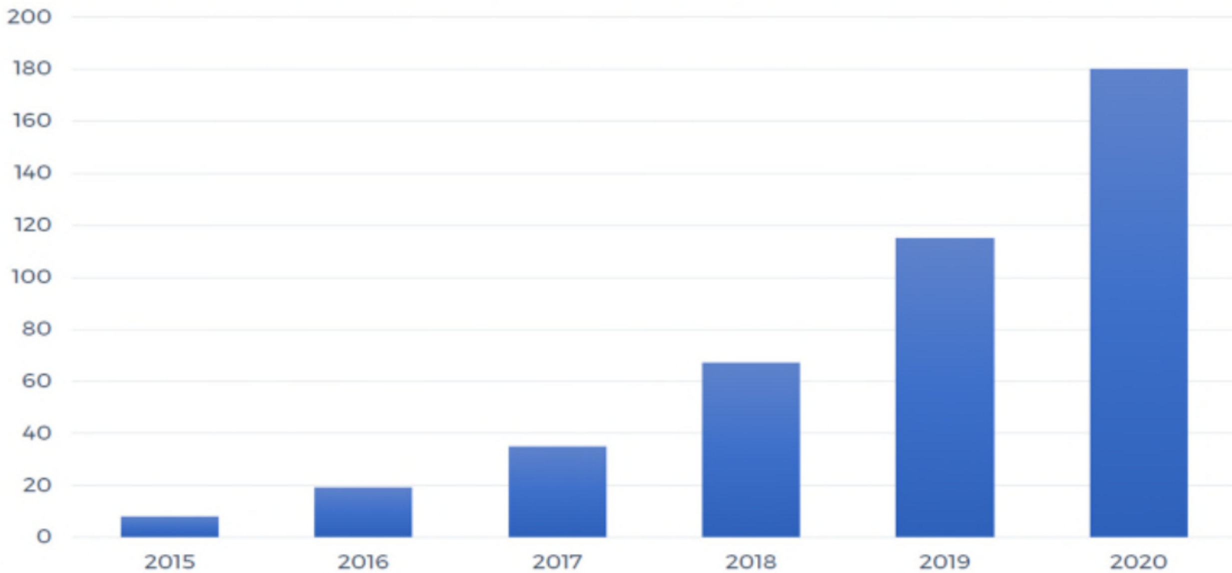


Figure 9 - Development of battery mega factories

Declining cost of Li batteries used in EVs (USD/kWh), 2014-2020[17]

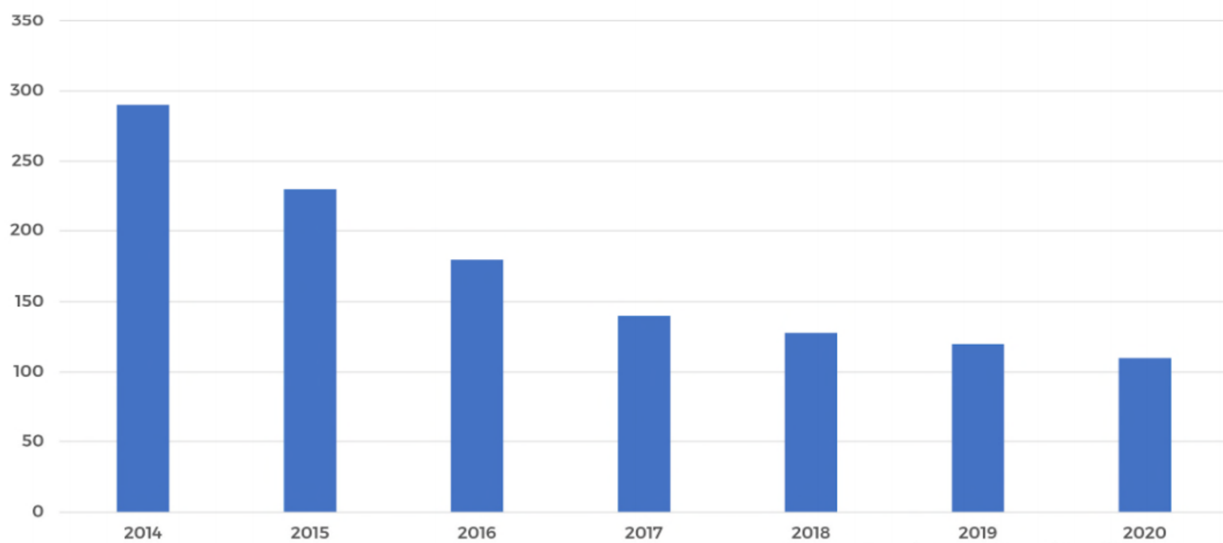


Figure 10 – Declining price of EV battery production

[16]Source: Benchmark Mineral Intelligence. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2021/02/THE-GLOBAL-BATTERY-ARMS-RACE-LITHIUM-ION-BATTERY-GIGAFACTORIES-AND-THEIR-SUPPLY-CHAIN.pdf

[17] Source: Benchmark Mineral Intelligence. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2021/02/THE-GLOBAL-BATTERY-ARMS-RACE-LITHIUM-ION-BATTERY-GIGAFACTORIES-AND-THEIR-SUPPLY-CHAIN.pdf

Medium and heavy-duty (M&HD) vehicles will take longer to achieve parity in both price and functionality. Cheaper batteries only solve half of the problem for M&HD vehicles. Even though ZEVs are more efficient than ICE vehicles, EVs tend to be much heavier than equivalent ICE vehicles as the energy density of batteries is much lower than that of fossil fuels.

M&HD vehicles require large battery packs to be effective, and as such the large battery pack increases the gross vehicle weight. And since legal limits of roadway maximum gross vehicle weight ratings are unlikely to change for road maintenance and safety reasons, the increased vehicle weight results in a reduced carrying capacity for M&HD EVs. Naturally the smaller the payload a vehicle can carry, the less effective it will be as a hauler.

Automakers are continuing to expand their ZEV offerings. The first vehicles to be electrified will be high end passenger vehicles and over the coming years would be the M&HD vehicles.

ELECTRIC VEHICLE SUPPLY EQUIPMENT DEPLOYMENTS

Now more than ever fleet managers need to coordinate with energy and facility managers to ensure the success of their fleet deployments over the long run. Too often charging infrastructure is an after thought for fleet managers as most facilities can support a handful of vehicles without major retrofits. But once the electrical capacity for the facility is reached, the cost of adding additional electrical capacity can exceed the price of the vehicle.

Therefore, fleet wide electrification planning is required to ensure that infrastructure installations are future proofed. Best practice is to install charging infrastructure in two phases. The first phase brings energy to where it will be needed in the future. The second phase is the installation of the charging infrastructure where and when it is needed.

<u>Indicative figures EV infrastructure project:</u>

AC Level 2

- Capital expenditure

7kW - $2,500 for the station, another $4,500 for install.

20kW - $4,000 for the station, another $8,000 for install.

- Operational expenditure

$20/port per month for Charging Station Management

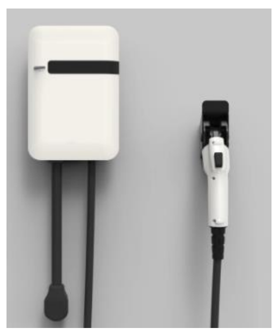


Figure 11 – Lite-on platinum Charging station (L2)

DCFC level 3

- Capital expenditure

25kW - $22,000 for the charger, another $25,000 for install.

50kW - $50,000 for the charger, another $50,000 for install.

120kW - $75,000 for the charger, another $75,000 for install.

- Operational expenditure

$50/port per month for Charging Station Management

Figure 11 – BTC power High Power DCFC (L3)

Location	Vehicles	EVSE	Est. Cost
All Fleet	49	22	$130,359

Figure 12 – Scenario 4 EVSE requirement

SECTION 7: ENERGY GHG IMPACTS

As the fleet decarbonizes, reliance on fossil fuels will decrease over time whereas demand for electricity will increase significantly, resulting in an overall decrease in GHGs (see figure 13). This will require electrical upgrade to the fleet depot. The below chart shows the changes in annual fuel and energy consumption for the vehicles in scope of this assessment over the next decade. If charging will be offered to employees or the public parking personal vehicles, then the demand for electricity will be even greater.

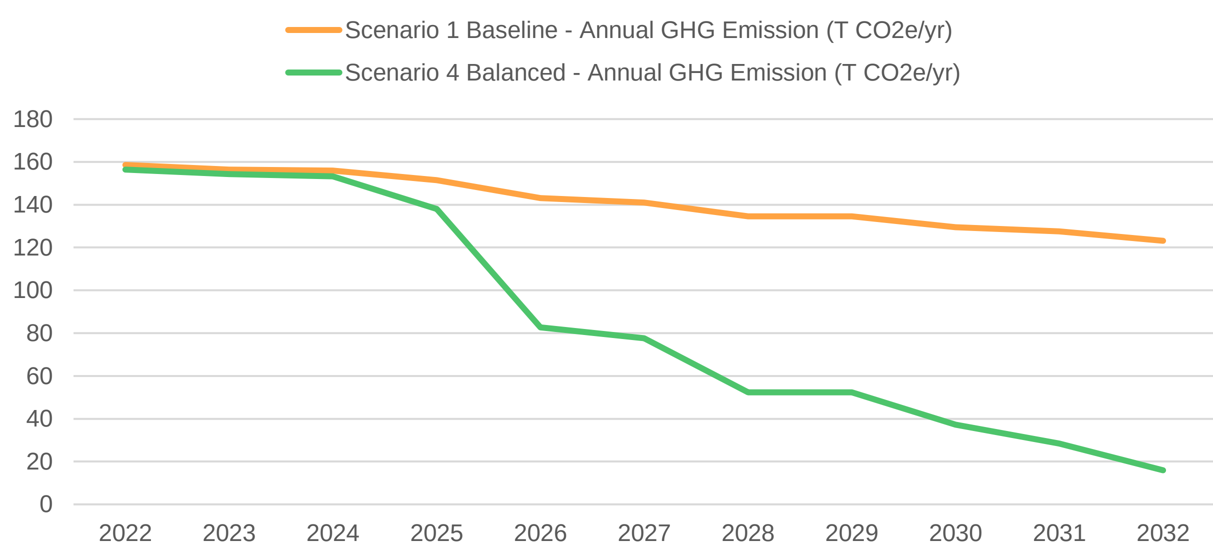


Figure 13 – Model reduction of GHG emissions over next 10 years under scenario 4

The BC methodological guidance for quantifying GHG emissions[18] has been used to prepare the below forecast. As per the guidance methodology, electric vehicles produce zero emissions at the tailpipe and are therefore not included in emissions reporting for mobile sources. However, the electricity consumed by an electric vehicle may very well be tracked as part of a building's plug load. The contribution to the building's plug load GHG emissions which derives from the ZEVs is included on the chart below, although it is hard to see in comparison to emissions form gasoline and diesel because of our clean energy grid in BC.

[18] https://www2.gov.bc.ca/assets/gov/environment/climate-change/cng/methodology/2018-pso-methodology.pdf

Methodological Equation:

$$Annual\ GHG\ Emissions = Emission\ Factor \times Annual\ Consumption$$

Emission Factor per L of Fuel or kWh of electricity:

	kg_CO2e/L	kg_CO2e/kWh
Gasoline (E5)	2.379	
Diesel (B4)	2.65	
Electricity (BC Hydro)		0.01067

Table 6 – Emissions Factors

Consumption Estimate by year:

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Electricity (kWh)	3,166	3,166	3,924	16,467	68,357	72,300	94,468	94,468	107,308	115,319	124,621
Gasoline (L)	131,352	125,811	124,848	111,923	63,678	59,399	37,777	37,777	24,191	16,738	6,138

Table 7 – Consumption Estimate by year

EMBODIED CARBON

Embodied carbon refers to the greenhouse gas emissions arising from the manufacturing, transportation, installation, maintenance, and disposal of materials. The manufacturing of electric vehicles can be more carbon intensive than internal combustion engines. As a large high-tech battery is more carbon intensive to produce than an empty fuel tank. However, the materials in the battery remain available for recycling, whereas the fuel combusted is gone at the end of the vehicle's life cycle. A recent environmental life cycle assessment, which factors in emissions associated with vehicle manufacturing, was commissioned by PlugInBC and the Fraser Basin Council. It concluded that "an EV charged in B.C. breaks even (pays off its environmental burden) within 30,000 km driven, and any distance driven beyond 30,000 km becomes carbon-negative."[19]

[19] https://www.bchydro.com/news/conservation/2021/ev-myths-busted.html

SECTION 8: COST BENEFIT ANALYSIS

ZEV replacements will have some financial impact on the organization which we have measured in dollars, and a benefit to the organization which we have measured in greenhouse gas emission reduction. Going electric will be very capital intensive, however, by acting early the RMOW could cut a decade worth of emissions in half. Figure 14 compares the costs under four scenarios.

“There are no solutions, there are only trade-offs; and you try to get the best trade-off you can get, that's all you can hope for.”

Thomas Sowell Economist

	Scenario 1 *Baseline / Like for Like Replacement (Replaced by ICE Vehicles)*	Scenario 2 Prioritize GHG Emission Reductions	Scenario 3 Minimize Total Cost of Ownership	Scenario 4 **Balanced** (ZEV would replace an ICE if it was less than 25% more expense)
10-year Total Cost ($)	$ 3,650,920	$ 4,127,221	$ 1,787,058	$ 3,960,147
Cumulative GHG Emissions (T CO2e)	1,556	915	1,071	949

Table 8 - Summary of Scenario Results

SCENARIO 1: LIKE FOR LIKE REPLACEMENT

In the “**Like for Like Replacement**” scenario – Current fleet vehicles are replaced at the end of their life by internal combustion engine (ICE) vehicles of a similar type *(e.g., vans replace vans)*. It is not anticipated the RMOW will follow this scenario; this scenario is intended as a theoretical baseline, against which the financial and GHG emissions implications of the other scenarios can be compared.

SCENARIO 2: PRIORITIZE GHG EMISSION REDUCTIONS

The second scenario "**Prioritize GHG Emission Reductions**" - Current fleet vehicles are replaced at the end of their life by ZEVs of a similar type of vehicle *(e.g., a ZEV van would replace an ICE van)*.

SCENARIO 3: MINIMIZE TOTAL COST OF OWNERSHIP FINANCIAL CASE

The third scenario "**Minimize Total Cost of Ownership"** prioritizes the financial case - Current fleet vehicles are replaced at the end of their life by which ever vehicle has the lowest total cost of ownership (TCO). High utilization duty cycle vehicles are replaced by a ZEV and low utilization duty cycle vehicles would be replaced with an ICE vehicle.

SCENARIO 4: BALANCED

In the fourth scenario "**Balanced**" - Current fleet vehicles are replaced at the end of their life by a ZEV if the TCO premium is less than 25%. The TCO premium is the extra cost for a ZEV verses a comparable ICE vehicle over the lifetime of the vehicle *(e.g., a ZEV van would replace an ICE van if it was less than 25% more expense).*

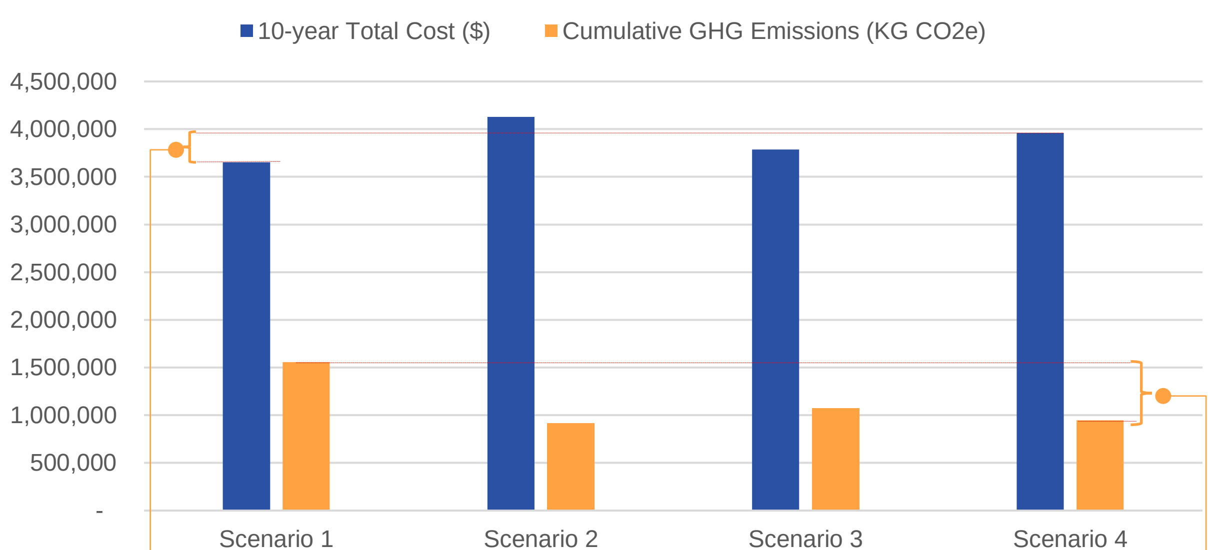


Figure 14: Cost Benefit Analysis of the four scenarios'

The marginal cost difference between the business-as-usual case (scenario 1) and the recommended solution (Scenario 4) is **$309,227**.

The reduction of emissions in scenario 4 would be **607 T CO_2e** from the baseline modeled in scenario 1.

SECTION 9: SUMMARY AND NEXT STEPS

This assessment provides guidance on how the RMOW could integrate ZEVs over the next decade into the fleet to achieve reductions in its greenhouse gas (GHG) emissions. More specifically, the plan includes:

- A review of existing fleet vehicles, their duty cycles, and replacement timeline.
- Recommendations for ZEV replacements and the required charging infrastructure required to support them.
- Energy requirements required to support a fleet powered by electricity rather than fossil fuels.
- A model to predict greenhouse gas emissions, and emission reductions associated with the transition of its fleet to rely more heavily on EVs.
- A cost benefit analysis demonstrating total cost of ownership savings and GHG emission reductions from adopting ZEVs.

KEY TAKEAWAYS

- The future energy demand of the fleet will be in the magnitude of **125 MWh**. Planning infrastructure deployments with this eventuality in mind will enable future proof designs and reduce costs over the long term.
- With the current market scenario, the availability of most ZEVs has been pushed farther out. On an average the lead-time of ZEV is 12-24 months.
- Replacing an ICE vehicle with an ZEV will be more economically viable only if it is utilized to a reasonable extent. ZEVs are preferred on duty cycles with high mileage.
- Today many electric vehicles are converted or produced in low volumes. As supply chains are developed and the technology matures, we expect ZEV purchase prices to reach parity with ICE vehicles. Price parity will be achieved in light duty vehicles first.
- Capital purchases of electric vehicles come at a varying premium to fossil fuel vehicles. The premium can be offset by lower fueling and maintenance costs over the life of the vehicle. Therefore, vehicles with the highest utilization are the most likely to be economically viable.

- Batteries are easily the most expensive component of an EV. As battery production increases, we expect the cost per kWh of a battery to drop below $100. This will be the key indicator of ZEV prices.
- The carbon intensity and cost of BC's energy production is very low due to the use of hydroelectric dams. This results in a win-win for ZEVs as they generate less than 3% of the GHG emissions to travel the same distance as a comparable ICE vehicle. Lower electricity tariffs also make ZEVs more cost competitive.
- As ZEVs produce zero tailpipe emissions they are therefore not included in emissions reporting for mobile sources. However, the electricity consumed by an electric vehicle may very well be tracked as part of a building's plug load.

The challenge to adopt electric vehicles today is lack of capable vehicles at a competitive price point when compared with fossil fuel vehicles. This will not be the case going forward as automakers are re-tooling to mass produce ZEVs. As that occurs order books for vehicles will open and supply won't be the main constraint in ZEV adoption. The bottleneck going forward will be lack of charging infrastructure as retrofitting existing sites to accommodate ZEVs will be large capital-intensive projects.

Now that the costs and benefits of de-carbonizing the fleet have been evaluated, and future energy demands required to support electrification have been calculated it is time to address the next challenge, the lack of charging infrastructure.

NEXT STEPS

To convert light duty fleet to ZEVs over the next decade, it is recommended that:

- A ZEV Infrastructure assessment be completed to determine the gap between the fleet facilities current and required electrical infrastructure to support ZEV adoption across the fleet.
- Vehicles are replaced at the end of their service life with equivalent ZEV versions, only when they are technically feasible and economically viable. This will start with cars, SUVs, minivans, and should include vans, light-duty trucks, heavy-duty trucks, and some off-road vehicles by 2026.
- Charging Stations should be installed before vehicles are electrified. This will start with Level 2 chargers to support the electric cars and SUVs and include

higher power Level 2 chargers and Level 3 fast chargers as larger electric vehicles are purchased.

ADDITIONAL RESEARCH

- A ZEV infrastructure assessment would determine if fleet depots can facilitate the adoption of ZEVs.
- To ensure optimal financial and environmental performance for all vehicles a life cycle optimization analysis can be performed. This is the preferred method of scheduling vehicle replacements.
- An analysis of renewable diesel could also be explored as low-carbon fuel alternative, including the supply availability, life-cycle cost, economic order quantity, storage capabilities and environmental impact.
- A risk analysis of vehicles utilized during emergency response, which includes resilience of electrical power, back-up power, and fuel supply systems required to provide energy to vehicles in case of a major event.
- More detailed analysis of the peak usage requirements for frontline, clearing and emergency vehicles would help to refine these projections. Analysis should include in-depth discussions with the relevant departments to better understand actual peak usage requirements, complete risk assessments, and consider alternative technologies like hydrogen fuel cell electric vehicles.

NOTES AND ASSUMPTIONS

ASSESSMENT LIMITATIONS

This assessment has been prepared by ChargeFWD for the exclusive use by the RMOW. The material in this assessment reflects the best judgment of ChargeFWD with the information made available to us at the time of preparation of this assessment. Any use a third party may make of this report, or any reliance on or decisions made based upon this assessment, is the responsibility of such third parties. ChargeFWD accepts no responsibility for damages suffered by a third party because of decisions made or actions taken based upon this assessment.

GLOSSARY OF TERMS AND DEFINITIONS

A	Amperes/ Amps
AHR	Account History Records
CEC	Canadian Electrical Code
BEV	Battery Electric Vehicle
D	Diesel Vehicle
EV	Electric Vehicle
EVEMS	Electric Vehicle Energy Management System
EVSE	Electric Vehicle Supply Equipment
HDT	Heavy-duty truck, Class 7-8.
ICE	Internal Combustion Engine
SUV	Sport utility vehicle
kW	Kilowatt - Unit of electrical power (1kW = 1000W)
kWh	Kilowatt-hour – Unit of energy or electrical consumption
LDT	Light-duty vehicles, Class 1 though 2H, i.e., F-150.
Load Sharing	Multiple EVSE share a single circuit
Load Management	Autonomous disconnection of circuits
M&HD	Medium and Heavy-duty Vehicles, Class 2G through 8
PHEV	Plug-in Hybrid Electric Vehicle
TCO	Total Cost of Ownership
T CO2e	Metric Tonne of Carbon Dioxide Equivalate
V	Voltage
X	Gasoline Vehicle
ZEV	Zero-Emissions Vehicle

APPENDIX A

For the fleet assessment analysis, we have considered the following vehicles.

Make	Model	Lead-time
Audi	E-Tron	1-6 Months
BYD	6F	12-24 Months
BYD	8TT	12-24 Months
BYD	8Y	12-24 Months
Canoo	MPDV	24+ Months
CEV	Might E Truck	1-6 Months
Chevrolet	Bolt EUV	1-6 Months
Chevrolet	Bolt EV	1-6 Months
Chevrolet	Silverado EV	24+ Months
Chrysler	Pacifica PHEV	1-6 Months
ELMS	UD	12-24 Months
ELMS	UU	12-24 Months
EVT Motors	Logistics Van	1-6 Months
Ford	E-Transit	12-24 Months
Ford	F-150 Lightning	24+ Months
Ford	Mach-E	1-6 Months
GM	Brightdrop EV600	24+ Months
GM	Hummer EV	24+ Months
GP Motor	EV Star	6-12 Months
GP Motor	EV Star CC	6-12 Months
GP Motor	EV Start Cargo	6-12 Months
GP Motor	EV Start Cargo+	6-12 Months
Hyundai	Ioniq 5	6-12 Months
Hyundai	Ioniq EV	1-6 Months
Hyundai	Ioniq PHEV	1-6 Months
Hyundai	Kona EV	1-6 Months
Kia	Niro EV	1-6 Months
Kia	Niro PHEV	1-6 Months
Kia	Soul EV	1-6 Months
Lightning eMotors	F59 Step Van	6-12 Months
Lightning eMotors	Transit 350HD Van	12-24 Months
Lightning eMotors	Transit Passenger Van	12-24 Months
Lion Electric	Lion6	12-24 Months
Lion Electric	Lion8	12-24 Months
Mack	LR Electric	12-24 Months

Make	Model	Lead-time
Motiv Power	EPIC E-450	6-12 Months
Motiv Power	EPIC F-53	6-12 Months
Nissan	Leaf	1-6 Months
Phoenix Motorcars	ZEUS 500	24+ Months
Polaris	Ranger EV	1-6 Months
Rosenbauer	Rt Electric Firetruck	24+ Months
Tesla	Model 3	6-12 Months
Tesla	Model S	6-12 Months
Tesla	Model X	6-12 Months
Tesla	Model Y	6-12 Months
Toyota	Prius Prime	1-6 Months
Volvo	XC40 Recharge	1-6 Months
VW	BUZZ	24+ Months
VW	ID.4	6-12 Months

APPENDIX B

Summary of the vehicle replacement road map under scenario 4.

CURRENT YEAR/MAKE/MODEL	ASSET ID	REPLACE. YEAR	LIKE FOR LIKE REPLACEMENT (SCENARIO 1)	ZEV REPLACEMENT (SCENARIO 2)	RECOMMENDED REPLACEMENT (SCENARIO 4)
2009 Chevrolet Express	V367	2022	Van (ICE)	Van (BEV)	Van (BEV)
2008 Chevrolet Express	V358	2022	Van (ICE)	Van (BEV)	Van (ICE)
2012 Toyota RAV4	V414	2024	Small SUV (ICE)	Small SUV (BEV)	Small SUV (BEV)
2012 Ford Transit Connect	V410	2024	Van (ICE)	Van (BEV)	Van (ICE)
2009 Ford F-150	V371	2025	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)
2013 Toyota Prius	V435	2025	Hatchback (ICE)	Hatchback (BEV)	Hatchback (BEV)
2013 Ford F-150	V430	2025	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)
2013 Chevrolet Silverado	V422	2025	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)
2013 Chevrolet Silverado	V421	2025	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)
2011 Ford F-150	V402	2025	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)
2014 Toyota RAV4 AWD	V455	2026	Small SUV (ICE)	Small SUV (BEV)	Small SUV (BEV)
2014 Nissan Frontier Truck	V460	2026	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2014 Nissan Frontier Truck	V453	2026	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2013 Nissan Frontier Truck	V432	2026	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2014 Toyota Prius	V450	2026	Hatchback (ICE)	Hatchback (BEV)	Hatchback (BEV)
2014 Nissan Frontier Truck	V452	2026	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2014 Toyota RAV4	V457	2026	Small SUV (ICE)	Small SUV (BEV)	Small SUV (BEV)
2012 Toyota Tacoma	V412	2026	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2014 Ford F-150	V444	2026	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)
2013 Nissan Frontier Truck	V433	2026	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2014 Ford F-150	V461	2026	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)
2014 Chevrolet Express	V440	2026	HD Van (ICE)	HD Van (BEV)	HD Van (BEV)
2014 Ford F-150	V454	2026	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)

CURRENT YEAR/MAKE/MODEL	ASSET ID	REPLACE. YEAR	LIKE FOR LIKE REPLACEMENT (SCENARIO 1)	ZEV REPLACEMENT (SCENARIO 2)	RECOMMENDED REPLACEMENT (SCENARIO 4)
2012 Toyota Tacoma	V413	2026	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2014 Nissan Frontier Truck	V458	2026	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (ICE)
2014 Nissan Frontier Truck	V451	2026	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (ICE)
2015 Nissan Frontier Truck	V468	2027	Hatchback (ICE)	Hatchback (BEV)	Hatchback (BEV)
2015 Nissan Frontier Truck	V467	2027	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2016 Ford F-150	V489	2028	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)
2016 Toyota Prius	V477	2028	Hatchback (ICE)	Hatchback (BEV)	Hatchback (BEV)
2016 Nissan Frontier Truck	V484	2028	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2016 Nissan Rogue	V478	2028	Small SUV (ICE)	Small SUV (BEV)	Small SUV (BEV)
2016 Ford F-150	V493	2028	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)
2016 Nissan Leaf	V473	2028	Hatchback (BEV)	Hatchback (BEV)	Hatchback (BEV)
2016 Toyota RAV4	V479	2028	Small SUV (ICE)	Small SUV (BEV)	Small SUV (BEV)
2016 Toyota Tacoma	V486	2028	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2016 Ford Transit	V471	2028	Van (ICE)	Van (BEV)	Van (BEV)
2016 Ford F-150	V475	2028	Pickup (ICE)	Pickup (BEV)	Pickup (ICE)
2018 Nissan Frontier Truck	V499	2030	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2018 Chevrolet Volt	V515	2030	Hatchback (PHEV)	Hatchback (BEV)	Hatchback (BEV)
2018 Nissan Frontier Truck	G92K7YX31T4R	2030	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)
2018 Mitsubishi Outlander	V512	2030	SUV (ICE)	SUV (BEV)	SUV (BEV)
2018 Nissan Frontier Truck	V516	2030	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (ICE)
2019 Chevrolet Silverado LD	V526	2031	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)
2019 Chevrolet Silverado	V522	2031	Pickup (ICE)	Pickup (BEV)	Pickup (BEV)
2019 Toyota RAV4 Hybrid	V524	2031	Small SUV (ICE)	Small SUV (BEV)	Small SUV (BEV)
2019 Toyota RAV4 Hybrid	V525	2031	Small SUV (ICE)	Small SUV (BEV)	Small SUV (BEV)
2020 Ford Escape	V540	2032	Small SUV (ICE)	Small SUV (BEV)	Small SUV (BEV)
2020 Chevrolet Colorado	V532	2032	Light Pickup (ICE)	Light Pickup (BEV)	Light Pickup (BEV)

Vehicle Examples for each Vehicle Category grouped by drivetrain defined by Weight Class and Body Type.

Drivetrain: ICE (internal combustion engine)					
GVWR	**Vehicle Category**	**EXAMPLE 1**	**EXAMPLE 2**	**EXAMPLE 3**	**EXAMPLE 4**
Class 1A	ROV (ICE)	POLARIS RANGER			
Class 1A	ATV (ICE)	HONDA TRX500			
Class 1A	Snowmobile (ICE)	BRP SKIIDOO			
Class 1B	Light Pickup (ICE)	DAIHATSU HIJET			
Class 1B	Hatchback (ICE)	TOYOTA PRIUS			
Class 1B	Sedan (ICE)	HONDA INSIGHT	HYUNDAI SONATA HYBRID	HONDA CIVIC HYBRID	FORD TAURUS
Class 1B	Small SUV (ICE)	SUZUKI VITARA	TOYOTA RAV 4	FORD ESCAPE HYBRID	NISSAN ROGUE
Class 1C	Cargo Van (ICE)	NISSAN NV200			
Class 1C	Small SUV (ICE)	NISSAN ROGUE	TOYOTA RAV 4	FORD ESCAPE HYBRID	
Class 1C	Light Pickup (ICE)	FORD RANGER	CHEVROLET COLORADO	NISSAN FRONTIER	
Class 1D	Cargo Van (ICE)	FORD TRANSIT	DODGE RAM PROMASTER CITY		
Class 1D	Light Pickup (ICE)	FORD RANGER	CHEVROLET COLORADO	NISSAN FRONTIER	
Class 1D	Minivan (ICE)	CHRYSLER GRAND CARAVAN			
Class 1D	Van (ICE)	FORD TRANSIT	DODGE RAM PROMASTER CITY		
Class 1D	SUV (ICE)	NISSAN ROGUE	TOYOTA RAV 4	FORD ESCAPE HYBRID	
Class 2E	Minivan (ICE)	CHRYSLER GRAND CARAVAN			
Class 2E	Pickup (ICE)	FORD F150	DODGE RAM 1500	CHEVROLET SILVERADO 1500	GMC SIERRA 1500
Class 2E	SUV (ICE)	NISSAN ROGUE	TOYOTA RAV 4	FORD ESCAPE HYBRID	
Class 2F	Pickup (ICE)	FORD F150	CHEVROLET SILVERADO 1500		
Class 2F	Cargo Van (ICE)	FORD E250	CHEVROLET EXPRESS	FORD TRANSIT 250	FORD TRANSIT 150
Class 2G	Cargo Van (ICE)	FORD E250	CHEVROLET EXPRESS	FORD TRANSIT 250	FORD TRANSIT 150
Class 2G	Pickup (ICE)	FORD F250			
Class 2H	HD Van (ICE)	FORD TRANSIT	DODGE RAM PROMASTER CITY		
Class 2H	Cargo Van (ICE)	FORD E350	NISSAN NV		
Class 2H	HD Pickup (ICE)	FORD F250	CHEVROLET SILVERADO 2500		
Class 3:	Cargo Van (ICE)	FORD TRANSIT T350HD			

Drivetrain: ICE (internal combustion engine) continued...					
EXAMPLE 1	EXAMPLE 1	EXAMPLE 1	EXAMPLE 1	EXAMPLE 1	EXAMPLE 1
Class 3:	Chassis Cab (ICE)	FORD F450			
Class 3:	HD Pickup (ICE)	FORD F350			
Class 4:	Chassis Cab (ICE)	FORD F450	DODGE RAM 4500		
Class 4:	Cutaway (ICE)	FORD E350			
Class 4:	Cutaway (ICE)	DYNAMIC GIRARDIN	DYNAMIC AEROTECH		
Class 5:	Chassis Cab (ICE)	FORD F550	DODGE RAM 5500		
Class 5:	Step Van (ICE)	FREIGHTLINER MT45			
Class 5:	Stripped Chassis (ICE)	FORD F550	FORD F450		
Class 5:	Truck (ICE)	PETERBILT ELGIN 220	AUTOCAR ELGIN		
Class 6:	Chassis Cab (ICE)	FORD F550	DODGE RAM 5500		
Class 6:	Truck (ICE)	PETERBILT ELGIN 220	AUTOCAR ELGIN		
Class 7:	Truck (ICE)	PETERBILT ELGIN 220	AUTOCAR ELGIN		
Class 8:	Type C School Bus (ICE)	BLUE BIRD			
Class 8:	Refuse Truck (ICE)	MACK LR			
Class 8:	Fire Truck (ICE)	FIRE TRUCK			
Class 8:	Chassis Cab (ICE)	FORD F550	DODGE RAM 5500		
Class 8:	Special Purpose (ICE)	SEWER FLUSH VAC TRUCK			
Class 8:	Truck (ICE)	FREIGHTLINER 114SD	INTERNATIONAL (IHC) 7600	INTERNATIONAL (IHC) SF667	KENWORTH T800

Drivetrain: PHEV (Plug-In Hybrid Vehicle)					
GVWR	Vehicle Category	EXAMPLE 1	EXAMPLE 2	EXAMPLE 3	EXAMPLE 4
Class 1B	Hatchback (PHEV)	KIA NIRO PLUG-IN HYBRID			
Class 1B	Sedan (PHEV)	HYUNDAI IONIQ PLUG-IN HYBRID	HONDA CLARITY PLUG-IN HYBRID	TOYOTA PRIUS PRIME	
Class 1B	Small SUV (PHEV)	HYUNDAI IONIQ PLUG-IN HYBRID	HONDA CLARITY PLUG-IN HYBRID	TOYOTA PRIUS PRIME	
Class 1C	Small SUV (PHEV)	FORD ESCAPE PLUG-IN HYBRID	MITSUBISHI OUTLANDER PHEV AWD	SUBARU CROSSTREK HYBRID AWD	TOYOTA RAV4 PRIME
Class 1C	Light Pickup (PHEV)	FORD RANGER PLUG-IN HYBRID			
Class 1D	Light Pickup (PHEV)	FORD RANGER PLUG-IN HYBRID			

Drivetrain: PHEV (Plug-In Hybrid Vehicle) continued…					
GVWR	Vehicle Category	EXAMPLE 1	EXAMPLE 2	EXAMPLE 3	EXAMPLE 4
Class 1D	Minivan (PHEV)	CHRYSLER PACIFICA HYBRID			
Class 1D	SUV (PHEV)	FORD ESCAPE PLUG-IN HYBRID	MITSUBISHI OUTLANDER PHEV AWD	SUBARU CROSSTREK HYBRID AWD	TOYOTA RAV4 PRIME
Class 2E	Minivan (PHEV)	CHRYSLER PACIFICA HYBRID			
Class 2E	SUV (PHEV)	FORD ESCAPE PLUG-IN HYBRID	MITSUBISHI OUTLANDER PHEV AWD	SUBARU CROSSTREK HYBRID AWD	TOYOTA RAV4 PRIME

Drivetrain: BEV (Battery Electric Vehicle)					
GVWR	Vehicle Category	EXAMPLE 1	EXAMPLE 2	EXAMPLE 3	EXAMPLE 4
Class 1A	ROV (BEV)	POLARIS RANAGER EV			
Class 1A	ATV (BEV)	ECO CHARGER QUAD			
Class 1A	Snowmobile (BEV)	TAIGA NOMAD			
Class 1B	Light Pickup (BEV)	CAN EV MIGHT-E TRUCK			
Class 1B	Hatchback (BEV)	CHEVROLET BOLT EV	FORD MUSTANG MACH-E	KIA NIRO EV	KIA SOUL EV
Class 1B	Sedan (BEV)	HYUNDAI IONIQ 5	POLESTAR 2	TESLA MODEL 3	
Class 1B	Small SUV (BEV)	HYUNDAI IONIQ 5	POLESTAR 2	TESLA MODEL Y	
Class 1C	Cargo Van (BEV)	FORD E-TRANSIT			
Class 1C	Small SUV (BEV)	KIA EV6	FORD MUSTANG MACH-E	VOLKSWAGEN ID.4	VOLVO XC40
Class 1C	Light Pickup (BEV)	ELECTRIC LIGHT PICKUP			
Class 1D	Cargo Van (BEV)	FORD E-TRANSIT			
Class 1D	Light Pickup (BEV)	ELECTRIC LIGHT PICKUP			
Class 1D	Van (BEV)	FORD E-TRANSIT			
Class 1D	SUV (BEV)	KIA EV6	FORD MUSTANG MACH-E	VOLKSWAGEN ID.4	VOLVO XC40
Class 2E	Pickup (BEV)	FORD F-150 LIGHTNING			
Class 2E	SUV (BEV)	KIA EV6	FORD MUSTANG MACH-E	VOLKSWAGEN ID.4	VOLVO XC40
Class 2F	Pickup (BEV)	FORD F-150 LIGHTNING			
Class 2F	Cargo Van (BEV)	FORD E-TRANSIT			
Class 2G	Cargo Van (BEV)	FORD E-TRANSIT			
Class 2G	Pickup (BEV)	FORD F-150 LIGHTNING			

Drivetrain: BEV (Battery Electric Vehicle) continued...					
GVWR	GVWR	GVWR	GVWR	GVWR	GVWR
Class 2H	HD Van (BEV)	FORD E-TRANSIT			
Class 2H	Cargo Van (BEV)	FORD E-TRANSIT			
Class 2H	HD Pickup (BEV)	FORD F-150 LIGHTNING			
Class 3:	Cargo Van (BEV)	LIGHTNING TRANSIT 350HD CARGO			
Class 3:	Chassis Cab (BEV)	LIGHTNING F-550 TRUCK	PHOENIX MOTORCARS ZEUS 500		
Class 3:	HD Pickup (BEV)	LIGHTNING F-550 TRUCK	PHOENIX MOTORCARS ZEUS 500		
Class 4:	Chassis Cab (BEV)	LIGHTNING F-550 TRUCK	PHOENIX MOTORCARS ZEUS 500		
Class 4:	Cutaway (BEV)	LIGHTNING F-550 TRUCK	PHOENIX MOTORCARS ZEUS 500		
Class 5:	Chassis Cab (BEV)	LIGHTNING F-550 TRUCK	PHOENIX MOTORCARS ZEUS 500		
Class 5:	Step Van (BEV)	MOTIV F-59	LIGHTNING F59 STEP VAN		
Class 5:	Stripped Chassis (BEV)	LIGHTNING F-550 TRUCK	PHOENIX MOTORCARS ZEUS 500		
Class 5:	Truck (BEV)	BYD 8TT	LION 8		
Class 6:	Chassis Cab (BEV)	LIGHTNING F-550 TRUCK	PHOENIX MOTORCARS ZEUS 500		
Class 6:	Truck (BEV)	BYD 8TT	LION 8		
Class 7:	Truck (BEV)	BYD 8TT	LION 8		
Class 8:	Type C School Bus (BEV)	BLUE BIRD ELECTRIC BUS			
Class 8:	Refuse Truck (BEV)	MACK LR ELECTRIC			
Class 8:	Fire Truck (BEV)	ROSENBAUER RT ELECTRIC FIRETRUCK			
Class 8:	Chassis Cab (BEV)	LIGHTNING F-550 TRUCK	PHOENIX MOTORCARS ZEUS 500		
Class 8:	Special Purpose (BEV)	SEWER FLUSH VAC E-TRUCK			
Class 8:	Truck (BEV)	BYD 8TT	LION 8	BYD 8R	