

July, 2022



Supporting Metro Vancouver's Fleet Climate Action Strategy

ASSESSING THE MARKET READINESS OF ZERO EMISSION FLEET VEHICLES

PREPARED BY: DANIEL STAUF, UBC SUSTAINABILITY SCHOLAR, 2022

PREPARED FOR: ADRIAN CHENG, PROJECT ENGINEER, METROFLEET

August 2022

Disclaimer

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organizations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

This project was conducted under the mentorship of Metro Vancouver staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of Metro Vancouver or the University of British Columbia.

Reproduced with permission of Metro Vancouver, with all rights reserved.

The author acknowledges that the work for this project took place on the unceded ancestral lands of the xwməθkwəy̓əm (Musqueam), Skwxwú7mesh (Squamish), Stó:lō and Səlílwətaʔ/Selilwitulh (Tseil-Waututh) Nations.

Executive Summary

The transportation sector represents a significant portion of global greenhouse gas (GHG) emissions, therefore reducing or eliminating tailpipe emissions is a critical step in achieving 2030 and 2050 climate change goals. This emphasizes the importance for government fleets to make the transition to zero emissions vehicles (ZEVs). As a business, Metro Vancouver (MV) needs to be prudent in their vehicle procurement while simultaneously being climate conscious. As such, this report performs a comparative analysis of the market readiness of ZEVs for each vehicle class, assigning a score at the class, vehicle manufacturer, and model level. The market readiness score is then used as an input into a vehicle procurement evaluation matrix, a comparative tool which provides a vehicle class/powertrain with an overall score from a weighted average of the market readiness, technology readiness, lifecycle emissions (LCE), and lifecycle cost (LCC). This will allow MV to make an informed decision while procuring new vehicles. The simplified assessment tool gives MV the flexibility to change key variables within the model as priorities change. In addition, the tool was developed in such a way that it may be refreshed with updated vehicle information as it becomes available. This way, MV will be able to continuously monitor the readiness of ZEVs for adoption into their fleet. The results from this assessment are to be used to update MV's Low Emissions Vehicle Standard providing MV with the information required to develop a cost and climate conscious vehicle procurement strategy.

Table of Contents

Disclaimer	2
Executive Summary	3
Abbreviations.....	5
Introduction.....	6
Zero Emissions Vehicles.....	6
Market Readiness Background	8
Market Readiness Assessment Factors	8
Market Readiness Tool Development	9
Assumptions.....	12
Benchmark Scoring.....	13
Tool User Guide.....	14
Technology Readiness	15
Vehicle Procurement Matrix.....	17
Analysis of Results	18
Conclusions.....	20
References.....	21
Appendix A: Summary of Vehicle Data.....	26
Appendix B: Score Results	34

Abbreviations

BEV	Battery Electric Vehicle
HD	Heavy Duty
LD	Light Duty
MD	Medium Duty
FCV	Fuel Cell Vehicle
ICEV	Internal Combustion Engine Vehicle
LCV	Light Commercial Vehicle
GHG	Greenhouse Gas
GVWR	Gross Vehicle Weight Rating
HEV	Hybrid Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
MV	Metro Vancouver
SUV	Sport Utility Vehicle
ZEV	Zero Emissions Vehicle
OEM	Original Equipment Manufacturer
LCE	Lifecycle Emissions
LCC	Lifecycle Cost

Introduction

The requirement for cities to work towards carbon neutrality is becoming more common as the effects of climate change begin to become apparent. Metro Vancouver (MV) is no different and in 2021, the MV Clean Air Plan was signed, committing the corporate fleet to 45% reduction of GHG emissions from 2010 levels by 2030, becoming carbon neutral by 2040, and zero emissions by 2050. The Clean Air Plan also outlines the actions required to be taken by MV in order to achieve these climate goals. One required action is to overhaul the vehicle fleet to 100% zero emissions vehicles (ZEVs). This includes all classes of vehicles, which are at varying stages of market readiness. Adopting a technology, particularly a capital-intensive one like a vehicle, before it is market-ready results in an elevated risk to the owner. It is for this reason that MV is looking for a tool to be developed that quantifies the market readiness of ZEVs in each vehicle class. Not all vehicle manufacturers are at the same level of market readiness, even within the same vehicle class. Therefore, this tool should be able to drill down to the manufacturer and model level, providing each with a market readiness score. This bottom-up approach will provide MV the visibility into not only what ZEV classes are market-ready, but also which manufacturers should be targeted for procurement. The tool will only provide a snapshot score of the current market readiness of ZEVs and can not provide a projection for future readiness. For this reason, the tool should be configured such that it can be easily updated to refresh the market readiness scores.

Zero Emissions Vehicles

Zero emissions vehicles are defined as any vehicle that produces no tailpipe emissions (Transport Canada, 2020). Currently, this includes battery-electric vehicles (BEV) and hydrogen fuel cell vehicles (FCV). While Transport Canada currently includes plug-in hybrid electric vehicles as ZEVs, they are not

included in this assessment as they still have the potential to produce tailpipe emissions via their internal combustion engine. This does not align with MVs goal of having a carbon-neutral fleet by 2050.

The following vehicle classes are included in the assessment:

Light Duty Sedans: These vehicles have a “three box design” in that there is a physically separated front end (engine bay), middle section (passenger compartment), and rear end (trunk) (J.D. Power, 2021). LD Sedans are commonly used for both city and highway transportation and are a popular choice as fleet vehicles due to their flexible engine options and reliability.

Light Duty Sport Utility Vehicles: SUV is a loose term however for the purposes of this study, SUVs are considered to be a station wagon like vehicle but built on a light-truck chassis. Traditionally built with 4-wheel drive to allow for off-road driving, 2-wheel drive SUVs were also included in this classification for the purposes of the study.

Light Duty Trucks: Trucks are classified based on their gross vehicle weight rating (GVWR) and are broken into classes with Class 1 being the lightest and Class 8 being the heaviest. Light Duty (LD) trucks encompass classes 1-3 with a GVWR of 0-14000 lbs (Badger, 2022).

Medium Duty Trucks: MD trucks are Class 4-6 with a GVWR range of 14001-26000 lbs

Heavy Duty Trucks: HD trucks are class 7-8 with a GVWR range of 26001-33000 lbs and above. In this study, MD and HD trucks are assessed together due to the relatively low number of ZEV models available, similar applications, and both classes manufacturers will offer trucks in both of these class categories.

Cargo Vans: Often referred to as light commercial vehicles (LCV), these vehicles are primarily used for last mile delivery, as well as for transporting goods and services.

Market Readiness Background

Market readiness is a parameter often measured by small technology producers to assess the readiness of their product for sale to the general public. In this case, market readiness is being used by the consumer (Metro Vancouver) to assess the risk of adopting a relatively new market technology for fleet assets. Adopting a non-market ready vehicle into a fleet presents a reliability risk as parts/service availability for these vehicles is not as established as that of a market ready vehicle. In addition, market ready vehicles are deemed to have a robust supply chain to meet consumer demands without being placed on significant back order.

Market Readiness Assessment Factors

Choosing appropriate factors by which to assess the market readiness of ZEVs was a critical step. A literature review was performed to see if a similar assessment had been performed however the results show other assessments were primarily qualitative in nature which leaves room for subjectivity. Through discussion with the project mentor, it was determined that the number of manufacturers, number of models, average generation of models, market share, and supply chain stability would be appropriate factors. The number of manufacturers and models is an important indicator of market readiness because it establishes the maturity of a product. In addition, having many makes/models available means the product is more likely to be available when required. The average generation of the models was chosen as an indicator of market readiness because it shows that the vehicle has been optimized for improved reliability, performance, and production costs. Generally, the higher the generation of a technology (not just vehicles), the more advanced it is therefore it is desirable to procure vehicles with a higher average generation. Having a low average generation of vehicles is an indicator that it has lots of room for improvement and may be less reliable or prone to defects. Market share is the most important indicator of market readiness as it shows how a product is being received by

the consumer. With the automotive industry being extremely competitive, vehicles having a high market share mean that consumers have tested them and are satisfied with their performance. Conversely, low market penetration is an indicator that a vehicle has not been used enough to be trusted by consumers. While none of these indicators alone may be used as an indicator of market readiness, a weighted average of the 4 will provide some insight into the readiness of the vehicles.

Initially, supply chain stability was chosen to be included as an indicator of market readiness. While this would be a valuable factor to measure for ZEVs, insufficient information was able to be collected to accurately quantify this for each ZEV manufacturer. Measurement of supply chain resiliency is something that can be done, however access to internal OEM information is required. Services are available for this from consulting companies such as Resilink (2017).

Market Readiness Tool Development

The first step in the development of the market readiness tool was to find all ZEV makes and models for each vehicle class. Importantly, only ZEVs that are available for sale in North America were included in the tool. These vehicles (separated into BEVs and FCVs for each class) were obtained from the website www.evplugndrive.ca (2022) and are summarized in Tables 1-2 below:

LD Sedan (BEV)	
Make	Model
BMW	i3
Chevrolet	BOLT
Kia	Soul EV
MINI	Cooper SE Electric
Nissan	LEAF
Porsche	Taycan
Tesla	Model 3
Tesla	Model S
Volkswagen	e-Golf
Mercedes	EQS
LD SUV (BEV)	
Make	Model
Mercedes	EQA
Hyundai	KONA

Hyundai	IONIQ electric
Tesla	Model X
Tesla	Model Y
Audi	e-tron
Jaguar	I-PACE
Ford	Mustang Mach-e
Kia	Niro
Rivian	R1S
Volkswagen	ID.4
Volvo	XC40 electric
Mazda	MX-30
LD Truck (BEV)	
Make	Model
Ford	F-150 Lightning
GM	Hummer EV
Rivian	R1T
Lordstown	Endurance
Chevrolet	Silverado EV
MD/HD Truck (BEV)	
Make	Model
Volvo	FH Electric
Volvo	FM Electric
Volvo	FE Electric
Volvo	FL Electric
Volvo	FMX Electric
Volvo	VNR Electric
Daimler	Freightliner eCascadia
Daimler	Freightliner eM2
Daimler	FCCC MT50e
Peterbilt	220EV
Peterbilt	579EV
Peterbilt	520EV
ELMS	Urban Utility
Kenworth	T680E
Kenworth	K270E
Nikola	Tre BEV
DAF	LF Electric
DAF	H2 Vehicle
Tesla	Tesla Semi
BYD	8TT
BYD	6F
BYD	6R
GreenPower	EV Star CC
GreenPower	EV Star CC RHD
GreenPower	EV Star CC Cargo+
Zeus	Z-19

Zeus	Z-22
Zeus	Z-26
Commercial Van (BEV)	
BrightDrop	Zevo 600
BrightDrop	Zevo 400
ELMS	Urban Delivery
Rivian	Commercial Van
GM	Ram ProMaster
Ford	E-Transit
Arrival	EV Van
Volkswagen	Crafter EV
Canoo	MPDV
Cenntro Auto Group	Logistar 400
Cenntro Auto Group	Logistar 200
Lightning eMotors	F-59
Lightning eMotors	T-350 HD
GreenPower	EV Star Cargo

Table 1: BEV Make/Model List

LD Sedan (FCV)	
Make	Model
Toyota	Mirai
LD SUV (FCV)	
Make	Model
Hyundai	NEXO
LD Truck (FCV)	
Make	Model
None	None
MD/HD Truck (FCV)	
Make	Model
Nikola	Tre FCEV
Nikola	Two FCEV
BYD	8R
Kenworth	K370E
DAF	XF H2
Hyzon	Class 8
Hyzon	Econic Refuse
Hyzon	Drayage
Hino	XL FCEV
Hyundai	Xcient
Commercial Van (FCV)	
Make	Model
None	None

Table 2: FCV Make/Model List

Once the makes and models were identified, the next step was to gather all required data for the market readiness factors for each manufacturer and model. Table 3 summarizes the data source utilized to populate each market readiness factor.

Market Readiness Factor	Data Collection Source
Vehicle Generation Number	https://www.autoevolution.com/
Vehicle Sales (Sedan, SUV, LD Truck) Total Vehicle Sales (Including ICEV/Hybrid)	https://www.goodcarbadcar.net/2021-canada-passenger-car-sales-figures-by-model/
Vehicle Sales (MD/HD Truck, Commercial Van)	OEM Annual Reports

Table 3: Market Readiness Factor Data Collection Sources

Sales numbers were gathered for the 2021 year for both Canada and the United States. These sales numbers were then combined in order to calculate the percent market share for North America at both the model, and manufacturer level. This exercise was completed separately for both BEVs and FCVs. A summary of the collected data is shown in Appendix A.

Assumptions

Not all required data was available from the sources listed in Table 3. As such, some assumptions had to be made in order to fill in the data gaps. These assumptions are listed below:

Assumption Number	Assumption	Reason for Assumption	Basis for Assumption	Impacted Variable
1	The ratio of Kia Soul EV to Kia Niro EV sales is the same as their ICEV counterparts.	Kia Soul EV sales unavailable	Judgement used as basis for this assumption	Kia Soul – Model score Kia – Manufacturer score LD Sedan (BEV) – Class score
2	The breakdown of BEV vs ICEV sales for the Volkswagen Golf is equivalent to that of the MINI Cooper SE	Volkswagen Golf EV sales unavailable	Volkswagen Golf and MINI Cooper SE are similar models thus it is deemed to be reasonable for them to have a similar breakdown of BEV vs ICEV sales	Volkswagen Golf – Model score Volkswagen – Manufacturer score LD Sedan (BEV) – Class score

3	The breakdown of BEV vs ICEV sales for the Hyundai Ioniq is equivalent to that of the MINI Cooper SE	Hyundai Ioniq EV sales unavailable	Hyundai Ioniq and MINI Cooper SE are similar models thus it is deemed to be reasonable for them to have a similar breakdown of BEV vs ICEV sales	Hyundai Ioniq – Model score Hyundai – Manufacturer score LD SUV (BEV) – Class score
4	The model breakdown of Rivian vehicle deliveries in 2021 was equivalent to what they announced as their goal in Q2, 2021 (Rivian, 2021)	Rivian model sales unavailable (only total vehicle sales)	Rivian announced very specific goals for the breakdown of their model deliveries therefore it is likely that this will have been done based on market research for projected demand for each model	Rivian R1S – Model score Rivian R1T – Model score Rivian Van – Model score Rivian – Manufacturer score LD SUV – Class score LD Pickup Truck (BEV) – Class score
5	One third of Volvo’s electric vehicle deliveries in 2021 (BEV & PHEV) were BEV.	Volvo EV sales unavailable (only total EV + PHEV sales)	As per motortrend (2022), in 2021, there were approximately double the number of PHEV sales than BEV sales	Volvo XC40 – Model score Volvo – Manufacturer score LD SUV (BEV) – Class score
6	Volvo’s 121 electric MD/HD truck deliveries in 2021 were evenly distributed amongst their 5 available models and 25% of these deliveries were made in North America.	Volvo trucking EV sales unavailable (only total vehicle sales)	The 5 available models are all the same generation and launched at similar times therefore it was deemed reasonable to assume that vehicle deliveries would be approximately equal for all models. 25% of the deliveries were assumed to be in North America as that is the fraction of ICEV deliveries in North America (as per Volvo annual report page 8)	Volvo FH/FM/FE/FL/FMX/VNR – Model scores
7	Of the 200 total BYD trucks sold in the United States, one half of them occurred in 2021 and they were evenly distributed amongst their 4 available models.	2021 BYD North America sales unavailable	BYD began selling electric trucks in North America in 2015 (trucks.com, 2017) and has experienced exponential growth. 200 total deliveries had been made as of 2021 and the 100 th sale was made in 2021 (BYD, 2020)	BYD 8TT/6F/6R – Model scores

8	45 Lion electric trucks were delivered in 2021 but the breakdown of each model and location of sales was not available in the annual report. It is assumed that the sales are equally distributed for each model and that the location breakdown was the same as their total vehicle sales (68% of their 196 total vehicle sales were in Canada).	Lion model sales unavailable (only total vehicle sales)	All of Lion's models are the same generation and were launched at similar times therefore it was deemed reasonable to assume that vehicle deliveries would be approximately equal for both models	Lion 6/8 – Model scores
9	Lightning eMotors electric van deliveries in 2021 were equally distributed amongst their 2 available models.	Lightning model sales unavailable (only total vehicle sales)	All of Lightning's models are the same generation and were launched at similar times therefore it was deemed reasonable to assume that vehicle deliveries would be approximately equal for both models	Lightning F59/T-350 – Model scores
10	Total commercial van sales in 2021 were equal to 2020.	2021 commercial van sales unavailable	Total vehicle sales stayed relatively consistent between 2020 and 2021 for other vehicle classes (goodcarbadcar, 2022)	Commercial Van – All model scores Commercial Van – All manufacturer scores Commercial Van (BEV) – Class score
11	Hyzon's 87 FCEV deliveries in 2021 were equally distributed amongst their 5 available models and 75% of them occurred in North America (where they are based).	Hyzon model sales unavailable (only total vehicle sales)	All of Hyzon's models are the same generation and were launched at similar times therefore it was deemed reasonable to assume that vehicle deliveries would be approximately equal for all models	Hyzon Class 8/Econic Refuse/Drayage – Model scores
12	All vehicles that are available for sale in the USA will also be available in Canada eventually.	At the moment, many EVs are available in the USA but not in Canada	Deemed to be a reasonable assumption as per discussion with project mentor	None

13	The average generation of ICEV MD/HD trucks is the same as the average of the other classes of ICEVs	Information unavailable from OEM website	All classes of ICEVs have been around for approximately the same amount of time therefore it is reasonable to assume that they have advanced their models at the same rate	MD/HD Trucks – Average generation score
----	--	--	--	---

Benchmark Scoring

With the raw data summarized, it is required to be measured against a benchmark that is considered 100% market-ready. This will allow each ZEV class, manufacturer, and model to be given a percent market-ready score based on how they perform relative to the benchmark. ICEV data from 2021 was chosen as the benchmark data as it is deemed that ICEVs are 100% market ready. It should be noted that the 2020 COVID-19 pandemic impacted total vehicle sales (goodcarbadcar, 2022) and while there was a recovery in 2021, vehicle sales have not returned to 2019 levels. As a result, market readiness scores may be skewed when using 2021 ICEV vehicle data as a baseline. As ICEV sales were calculated as a function of ZEV sales (see formula below), 2021 ICEV values had to be used as a baseline to compare 2021 ZEV vehicles. For LD Sedans, LD SUVs, and LD Trucks, the manufacturer/model list was obtained from <https://www.carmodelslist.com/car-manufacturers/>. Generation number was obtained from the same website as the ZEVs (<https://www.autoevolution.com/>). For MD/HD Trucks, <https://www.carlogos.org/truck-brands/> was used to obtain the manufacturer list then the number of models/generation number for each manufacturer was obtained from the manufacturer websites.

As only total ICEV sales were required for this assessment (which would then be used to determine the average sales per ICEV manufacturer/model), ICEV vehicle sales were taken to be the difference between total vehicle sales and the sum of all non-ICEV vehicle sales. With hybrid (HEV + PHEV) sales found to make up 5% of total vehicle sales (motortrend, 2021), ICEV vehicle sales were calculated using the following formula:

$$S_{ICEV,In\ Class} = S_{Total,In\ Class} - S_{BEV,In\ Class} - S_{FCV,In\ Class} - 0.05S_{Total,In\ Class}$$

This formula is only applicable for the LD Sedan, SUV, and LD Truck classes. For MD/HD trucks and commercial vans, there are no hybrid models therefore

$$S_{ICEV,In\ Class} = S_{Total,In\ Class} - S_{BEV,In\ Class} - S_{FCV,In\ Class}$$

For LD Sedans, SUVs, LD trucks, and Commercial Vans $S_{Total,In\ Class}$ was taken from

<https://www.goodcarbadcar.net/>. For MD/HD trucks, $S_{Total,In\ Class}$ was back-calculated using the reported market share from PACCAR. As per PACCAR's annual report (2022), their 250,000 HD retail truck sales constituted 29.2% market share in North America. This was back-calculated to 856,164 total HD truck sales. Their 83,700 MD retail truck sales constituted 19.8% market share. This was back-calculated to 422,727 total MD truck sales. $S_{Total,In\ Class}$ for MD/HD trucks is therefore $856,164 + 422,727 = 1,278,891$.

ICEV data is summarized in Table 7:

	Number of Manufacturers	Number of Models	Average Generation of Models	2021 Sales (North America)	2021 In Class Market Share (North America)
LD Sedan	36	184	5	3194879	88.14%
LD SUV	40	189	3	8284063	91.14%
LD Pickup Truck	14	29	4	3018298	94.97%
MD/HD Truck	10	82	4	1278631	99.98%
Van	8	17	4	442,671	99.74%

Table 7: ICEV Data

The final scoring step is to create an average score for each manufacturer, model, and vehicle class. As each of the factors do not all contribute equally to a vehicle's market readiness, weightings were applied to each factor in order to calculate a total score. These weightings were determined through discussion with the project mentor and are summarized in Table 8:

Factor Weightings				
	Number of Manufacturers	Number of Models	Average Generation of Models	2021 In Class Market Share (North America)
Class level	0.05	0.05	0.25	0.65
Manufacturer Level		0.1	0.3	0.6
Model Level			0.4	0.6

Table 8: Factor Weightings

The results of the scoring are shown in Appendix B.

Tool User Guide

As the intent of the tool is for it to be used multiple times until ZEVs are deemed market ready, it is important that it be as user-friendly as possible to allow for easy updating. As the sales data uses annual numbers, the tool was designed to be updated on an annual basis. The steps for both updating the existing vehicle data as well as adding a new vehicle are outlined below:

Update Existing Vehicle Data

1. Navigate to the BEV tab (or FCV to update a fuel cell vehicle). The cells that require updating are highlighted in green.
2. Locate the vehicle(s) to be updated in the respective class.
3. Enter the current generation of the vehicle (search for the model at <https://www.autoevolution.com/>)
4. For LD Sedans, SUVs, and Trucks, enter annual sales numbers for Canada, and USA (data available at <https://www.goodcarbadcar.net/2021-canada-passenger-car-sales-figures-by-model/>)
5. For MD/HD Trucks and Commercial Vans, annual sales numbers are to be obtained from the OEM annual reports (normally available under the investor relations section of the OEM website).
6. Summary and scoring data will automatically update after the cells in green have been updated.

Add a New Vehicle

1. Navigate to the BEV tab (or FCV to add a fuel cell vehicle).
2. Find the grouping for the class of vehicle you would like to add (LD Sedan, LD SUV, LD Pickup, MD/HD Trucks, Commercial Van).
3. Add a new row to the desired grouping.
4. Enter the make/model.
5. Follow steps 3-5 of the "Update Existing Vehicle Data" instructions
6. Update the market share columns by dragging down completed cells.
7. Navigate to the Summary tab.
8. Expand the section you are looking to update (eg, BEV LD Sedan)
9. If adding a new model to an existing manufacturer, expand the manufacturer (click the + box) and add a new row. If adding a new manufacturer, do not expand any of the existing manufacturers and add 2 new rows.
10. Enter the make/model of the new vehicle in the respective cells.
11. Drag down the populated columns C through G to auto populate the data.
12. Ensure the manufacturer/class total cells are also updated to capture the new vehicle in their respective averages.
13. Navigate to the Scoresheet tab.
14. If adding a new model to an existing manufacturer, expand the manufacturer (click the + box) and add a new row. If adding a new manufacturer, do not expand any of the existing manufacturers and add 2 new rows.
15. Enter the make/model in the respective cells.

16. Drag down the populated columns C through G to auto populate the new scores (note, the scores for models, manufacturers, and vehicle classes have different formulas. Make sure the correct formulas are copied).
17. Ensure the manufacturer/class total cells are also updated to capture the new vehicle in their respective averages.

Technology Readiness

When making a decision on vehicle procurement, MV requires an understanding of the vehicle's market readiness, technology readiness, lifecycle emissions (LCE), and lifecycle costs (LCC). The LCE and LCA for the various ZEV classes were determined by a previous Sustainability Scholar report (Goulden, 2021). After the market readiness tool had been built, technology readiness was the final factor for consideration. Technology readiness is an important parameter because the more complex the application, the more likely it is that performance or reliability issues may be encountered with newer technologies. This is particularly true with emerging technologies like ZEVs. Technology readiness was therefore to be assessed by listing all of the required features of the ZEV to be procured by MV, with the technology readiness score decreasing as more features are added. The vehicle features contributing to the technology readiness score were developed through discussion with the project mentor and are listed in Table 9.

Category	Feature
Hydraulics	Hooklift
	Dump
	Crane
	Aerial
	Pump
	Compressor
Snow/Ice Response	Plow
	Salter
	Brine

Towing	Required
	Not Required
Electrical	Radio
	Aux Lighting
	Laptop
Fire Response	Pump – Wildfire Response
	Pump - Traditional
	Ladder
	Tanker
Miscellaneous	Air brakes – Truck
	Air brakes - Trailer
	Hydrovac
	All Wheel Drive

Table 9: Technology Readiness Features

Not all features contribute equally to the technology readiness of a vehicle as some are more advanced than others. As such, different weightings are available for each feature. At the time of writing this report, the weightings have been equally distributed amongst the features as the scholar is not qualified to judge the complexity of them. These may be adjusted in the tool at the user’s discretion.

Vehicle Procurement Matrix

With the four factors of technology readiness, market readiness, lifecycle emissions, and lifecycle cost specified for all vehicle classes, MV requested a vehicle procurement matrix be developed to score each vehicle class and powertrain. This was made in excel allowing the user to select their desired vehicle class and powertrain. The tool will then return the corresponding technology readiness, market readiness, lifecycle emissions, and lifecycle cost. The technology and market readiness scores were equal to the % readiness values directly from the tools. The LCE and LCC scores were taken to be the magnitude of the percent decrease from the highest in class value. For LCE, the highest value was ICEV for all vehicle classes. For LCC, the highest value changed depending on the selected vehicle class.

Of note, ZEV commercial vans were not differentiated as a vehicle class as part of the previous sustainability scholar study on lifecycle emissions and lifecycle cost. As such, the majority of LCE/LCC

scores are reported as “Not Available” for these vehicles. However, as per the B.C Best Practices Methodology for Reporting Greenhouse Gas Emissions document (2021), “Cargo Van” emissions can be captured the same way as LD pickup trucks. Therefore, the vehicle procurement matrix uses LD Truck lifecycle emissions for commercial vans.

Analysis of Results

As per the Appendix B results, the two most market ready zero emissions vehicles are the battery electric sedan and SUV with scores of 18.92% and 17.47% respectively. This is largely because they are the only two vehicle classes to have a meaningful market-share (7.69% and 4.24%). With market-share being the most heavily weighted factor in market readiness, it will be difficult for the other vehicle classes/powertrains to get a reasonable score without first securing a larger market-share.

The top two manufacturers for battery electric sedans are Chevrolet and Tesla with scores of 57.09% and 77.60% respectively. Chevrolet received this score because of the mature Chevrolet BOLT (3rd generation) whereas Tesla received its high score because of their large market-share (100% which means they have a larger market share than the average manufacturer of ICEVs). The two highest rated models of BEV sedans were the Chevrolet BOLT and Tesla model 3. This is due to a strong market share from both models (equal or greater than the average market share of an ICEV sedan).

The top two manufacturers for battery electric SUVs are Hyundai and Tesla with scores of 58.16% and 63.57% respectively. Hyundai scored highly in average generation of models and Tesla scored highly for market-share. Both of these scores showed performance close to that of ICEV manufacturers. The two highest rated models were the Hyundai KONA and Tesla Model Y. The KONA received a perfect score of 100% meaning it is just as market ready as an ICEV SUV. The Model Y received a score of 73.45% which is close to the market readiness of an ICEV. It has a market share equal or greater than that of an ICEV SUV however being a first-generation vehicle, it lost some points as it is not as mature as most ICEV SUVs.

Battery electric light duty pickup trucks scored very low with a market readiness of 3.92%. This is because they have not reached the market yet with minimal sales in North America. The Rivian R1T truck was the only BEV pickup to make a sale in 2021 in North America, delivering 897 trucks (see assumption number 5). However, with ~400,000 pre orders in place for the 5 available models, it is expected that in the coming years, the market readiness score for these BEV pickups will increase significantly.

Medium and Heavy Duty battery electric trucks received a market readiness score of 11.36%. Like LD pickups, these trucks have essentially no market-share but appear to be on the verge of rapid growth in the coming years. With 15 manufacturers and 29 models available in North America (close to that of ICEVs), it is expected that battery electric MD/HD truck sales will start to increase significantly in the coming years.

Battery electric commercial vans received a market readiness score of 11.62%. Similar to MD/HD trucks, these vehicles have yet to penetrate the market with significant sales as of yet however with the number of manufacturers and models available in North America being close to that of ICEVs (11 manufacturers and 13 models), it is expected that the market readiness score for commercial vans will significantly increase in the coming years. Of note, Rivian has entered an exclusive partnership with Amazon to deliver 100,000 of their commercial vans through to 2024. As of now, these vans are not available for order to anyone else (Rivian, 2021).

Fuel Cell Vehicles all scored quite low for market readiness with sedans being the only vehicle class with a notable score (11.2%). Of note, there is a relatively large number of manufacturers of FCV MD/HD trucks which is an indicator that there may be some improvement in market readiness for this vehicle class in the coming years. However, for the remaining vehicle classes, there is no indication that the market conditions will change in favor of fuel cell vehicles.

A summary of the vehicle procurement matrix scores is shown in Table 2.

LD Sedan	
Powertrain	Total Score
ICEV	52%
BEV	56%
FCV-Electrolysis	49%
FCV-NG	48%
SUV	
Powertrain	Total Score
ICEV	54%
BEV	56%
FCV-Electrolysis	48%
FCV-NG	47%
LD Truck	
Powertrain	Total Score
ICEV	50%
BEV	51%
FCV-Electrolysis	50%
FCV-NG	50%
MD Truck	
Powertrain	Total Score
ICEV	50%
BEV	59%
FCV-Electrolysis	53%
FCV-NG	53%
HD Truck	
Powertrain	Total Score
ICEV	50%
BEV	53%
FCV-Electrolysis	53%
FCV-NG	53%
Commercial Van	
Powertrain	Total Score
ICEV	50%
BEV	66%
FCV-Electrolysis	50%
FCV-NG	50%

Table 2: Vehicle Procurement Matrix Summary

This scoring summary has not included any technical additions to the vehicles therefore all technology readiness scores are 100%. In addition, the tool currently has all four factors equally weighted.

Therefore, the above scores are subject to change. However as currently written, battery electric

vehicles are the highest rated in each vehicle class. It is difficult to draw any further conclusions at this time as it is important that the factors be weighted as desired by MV.

Conclusion

For zero emissions vehicles, battery electric vehicles currently hold a significant advantage over fuel cell vehicles from both a market readiness, and total vehicle procurement score perspective. This is the case across all vehicle classes. In comparison to ICEVs, the battery electric sedan and SUV were the strongest performers, both of which are good candidates for immediate procurement. For the remaining vehicle classes/powertrains, it is recommended to wait until the market readiness improves before pursuing procurement. It is expected that 2022/2023 will be transformative years for zero emissions medium/heavy duty vehicles therefore the results of the next refresh of this tool should provide improved results for these vehicle classes.

During the literature review phase in which different tools for the quantification of market readiness were searched, it was found that this was a unique study and an equivalent tool does not seem to exist. As this is the first iteration of such a tool, it is expected that as it is used, opportunities for improvement will become apparent. This is strongly encouraged.

References

- Badger Truck and Auto Group (2022). *Truck Classification Explained*. Retrieved from <https://www.badgertruck.com/heavy-truck-information/truck-classification/>
- BMW Group (2022). *Sales figures for the MINI Electric almost doubled, MINI brand sales up 3.3 percent in 2021*. BMW Pressclub. Retrieved from <https://www.press.bmwgroup.com/global/article/detail/T0364395EN/sales-figures-for-the-mini-electric-almost-doubled-mini-brand-sales-up-3-3-percent-in-2021?language=en>
- Brightdrop (2022). *One year down and we're just getting started*. Brightdrop newsroom. Retrieved from <https://www.gobrightdrop.com/newsroom/brightdrop-hits-one-year-anniversary>
- Business Wire (2022). *Lightning eMotors Enters Canada's Commercial EV Market with Fully Electric Refrigerated Delivery Vehicles*. Retrieved from <https://www.businesswire.com/news/home/20211028005240/en/Lightning-eMotors-Enters-Canada%E2%80%99s-Commercial-EV-Market-With-Fully-Electric-Refrigerated-Delivery-Vehicles>
- BYD (2020). *BYD Delivers 100th Battery-Electric Truck In the United States*. Retrieved from <https://en.byd.com/news/byd-delivers-100th-battery-electric-truck-in-the-united-states/>
- Cenntro Electric Group (2022). *Full Year 2021 Earnings Presentation*. Retrieved from <https://ir.cenntroauto.com/static-files/b87b21df-0e2d-40a0-807b-359472cc1df2>
- Chase C (2022). *Top 5 best-selling BEVs in Canada for 2021*. The Charge. Retrieved from <https://thecharge.ca/listicles/top-5-best-selling-bevs-in-canada-for-2021/>
- Cody U (2022). *GMC Delivered One Hummer EV Edition 1 Before the End of 2021*. Muscle Cars and Trucks. Retrieved from <https://www.musclecarsandtrucks.com/gmc-hummer-ev-edition-1-sales-2021-vs-rivian/>
- Electric Last Mile Solutions (2022). *ELMS Announces Third-Quarter 2021 Financial Results*. Retrieved from <https://ir.electricleastmile.com/news/news-details/2021/ELMS-Announces-Third-Quarter-2021-Financial-Results/default.aspx#:~:text=Third%20Quarter%202021%20Highlights,30%2C%202021.>
- Fisher J (2020). *Mitsubishi Fuso phasing out sales in U.S. and Canada*. Fleet Owner. Retrieved from <https://www.fleetowner.com/equipment/trucks-trailers/article/21132481/mitsubishi-fuso-phasing-out-new-truck-sales-in-us-and-canada>
- Goulden S (2021). *Metro Vancouver Green Fleet Strategy Development: Life Cycle Costing and Emissions Tool for Procurement of Low Emission Fleet Vehicles*. 2021 Sustainability Scholars Report.
- Government of British Columbia (2022). *2021 B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions*. Ministry of Environment and Climate Change Strategy.
- GreenPower Motor Company (2022). *Transportation Evolved*. Investor Presentation, March 2022. Retrieved from <https://greenpowermotor.com/pdfs/GP-Investor-Deck-Mar-2022.pdf>
- GreenPower Motor Company (2022). *Management's Discussion and Analysis For the period ended June 30, 2021*. Retrieved from <https://greenpowermotor.com/investor-center/financial-reports/>
- GreenPower Motor Company (2022). *Management's Discussion and Analysis For the period ended September 30, 2021*. Retrieved from <https://greenpowermotor.com/investor-center/financial-reports/>

GreenPower Motor Company (2022). *Management's Discussion and Analysis For the year ended March 31, 2021*. Retrieved from <https://greenpowermotor.com/investor-center/financial-reports/>

Hawley, D (2021). *What is a Sedan?* J.D. Power. Retrieved from <https://www.jdpower.com/cars/shopping-guides/what-is-a-sedan>

Hyundai (2021). *Hyundai's XCIENT Fuel Cell Hitting the Road in California*. Press Release. Retrieved from <https://www.hyundainews.com/en-us/releases/3362#:~:text=Hyundai%20Motor%20teamed%20with%20public,the%20second%20quarter%20of%202023>.

Hyzon Motors (2022). *Hyzon Motors Inc. Reports Full Year and Fourth Quarter 2021 Results, Delivers Fuel Cell Vehicles, Playing a Pivotal Role in the Transition to Hydrogen*. Retrieved from <https://investors.hyzonmotors.com/news/news-details/2022/Hyzon-Motors-Inc.-reports-full-year-and-fourth-quarter-2021-results-delivers-fuel-cell-vehicles-playing-a-pivotal-role-in-the-transition-to-hydrogen-99bb85afa/default.aspx>

Jarratt E (2021). *Metro Supply Chain Group to deploy six electric trucks in 2021 with more to follow*. Electric Autonomy Canada. Retrieved from <https://electricautonomy.ca/2021/04/16/metro-supply-chain-electric-trucks/>

Kane M (2022). *US: Kia EV Sales Reached New Record in 2021*. Inside EVs. Retrieved from <https://insideevs.com/news/559872/us-kia-ev-sales-2021/>

Kane M (2022). *Mercedes-Benz Plug-In Car Sales in 2021: Up 69% to 227,458*. Inside EVs. Retrieved from <https://insideevs.com/news/562560/mercedes-plugin-car-sales-2021/>

Kia (2022). *Kia Canada achieves historic record-breaking year in 2021*. Retrieved from [https://www.kia.ca/en/about-kia/news/Kia-Canada-invests-\\$1-4M-to-support-communities-as-they-move-forwardAndrea-Dicks,-President,-Community-Foundations-of-Canada1](https://www.kia.ca/en/about-kia/news/Kia-Canada-invests-$1-4M-to-support-communities-as-they-move-forwardAndrea-Dicks,-President,-Community-Foundations-of-Canada1)

Kierstein A (2022). *2021 Sucked Generally, But Specifically was Good for Hybrids and EVs*. Motortrend. Retrieved from <https://www.motortrend.com/news/2021-hybrid-ev-vehicle-sales-us/>

Kothari S (2022). *2022 Ford E-Transit: Everything we know as of June 2022*. Top Electric SUVs. Retrieved from https://topelectricsuv.com/news/ford/ford-e-transit/#Production_Sales

Lion Electric (2022). *Earnings Call Presentation, Q4 2021*. Retrieved from https://s27.q4cdn.com/902820926/files/doc_financials/2021/q4/Q4-2021-Earnings-Presentation-VERSION-FINALE.pdf

Lordstown Motors (2022). *Lordstown Motors Reports Fourth Quarter and Fiscal Year 2021 Financial Results*. Retrieved from <https://investor.lordstownmotors.com/news-releases/news-release-details/lordstown-motors-reports-fourth-quarter-and-fiscal-year-2021>

Navistar (2021). *Penske First U.S. Fleet to Run International eMV Series*. Retrieved from <https://news.navistar.com/2021-10-11-Penske-First-U-S-Fleet-to-Run-International-R-eMV-TM-Series>

Nikola Corporation (2022). *Nikola Corporation Reports Fourth Quarter and Full Year 2021 Results*. Retrieved from https://nikolamotor.com/press_releases/nikola-corporation-reports-fourth-quarter-and-full-year-2021-results-155

Paccar (2022). *Paccar 2021 Annual Report*. Retrieved from <https://www.paccar.com/investors/>

Plug 'N Drive (2022). *Find your EV Match*. Retrieved from <https://ev.plugndrive.ca/>

Resilinc (2017). *A New Metric for Measuring Supply Chain Resiliency: An Introduction to Resilinc R Score and its Application to the High-Tech Industry Supply Chain*. Jointly published by Resilinc and the Global Supply Chain Resiliency Council.

Rivian (2022). *Q4 2021 Shareholder Letter*. Retrieved from <https://assets.rivian.com/2md5qhoeajym/7MVaHLcGevcUKE0QZZjzEZ/e3ac410e5f9676c894389c6bc844f1e7/Rivian-Q4-2021-Shareholder-Letter.pdf>

Rivian (2022). *Can I reserve an Amazon electric delivery van?* Frequently Asked Questions. Retrieved from <https://rivian.com/support/article/can-i-preorder-an-amazon-electric-delivery-van>

Schultz B (2022). *California Utility Service Company Will Be the First to Put Zeus All-electric Trucks to Work*. For Construction Pros. Retrieved from <https://www.forconstructionpros.com/trucks/trucks-accessories/medium-duty-trucks-class-4-6/article/22118953/zeus-electric-chassis-inc-california-utility-service-company-first-to-put-zeus-allelectric-trucks-to-work>

Tesla (2022). *2021 Impact Report*. Retrieved from https://www.tesla.com/ns_videos/2021-tesla-impact-report.pdf

Tesla (2022). *Q4 and FY2021 Update*. Retrieved from <https://ir.tesla.com/#tab-quarterly-disclosure>

Transportation Canada (2022). *Zero-emission Vehicles*. Retrieved from <https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles>

Trucks.com (2017). *Electric Truck and Bus Maker BYD on a Roll After Bumpy Start*. Retrieved from <https://www.trucks.com/2017/02/06/electric-truck-bus-byd/>

Volkswagen (2022). *Volkswagen of America Business Update: Q4 2021 – Total 2021*. Retrieved from <https://www.volkswagenag.com/en/news/2022/03/volkswagen-group-achieves-solid-results-in-2021-and-drives-forwa.html>

Volvo Group (2022). *Report on the Fourth Quarter and Full Year 2021*. Retrieved from <https://www.volvogroup.com/content/dam/volvo-group/markets/master/news/2022/jan/4169226-volvo-q4-2021-eng.pdf>

Volvo Group (2022). *Leading the Transformation: Volvo Group Annual and Sustainability Report 2021*. Retrieved from <https://www.volvogroup.com/content/dam/volvo-group/markets/master/investors/reports-and-presentations/annual-reports/annual-and-sustainability-report-2021.pdf>

Appendix A: Summary of Vehicle Data

BEV						
		Number of Manufacturers	Number of Models	Average Generation of Models	2021 Sales (North America)	2021 In Class Market Share (North America)
LD Sedan		9	9	2	245785	6.78%
LD SUV		9	11	2	350853	3.86%
LD Pickup Truck		5	5	0	898	0.03%
MD/HD Truck		15	29	1	219	0.02%
Van		11	13	0	1155	0.26%
FCV						
		Number of Manufacturers	Number of Models	Average Generation of Models	2021 Sales (North America)	2021 In Class Market Share (North America)
LD Sedan		1	1	2	2757	0.08%
LD SUV		1	1	1	422	0.00%
LD Pickup Truck		0	0	0	0	0.00%
MD/HD Truck		6	9	0	41	0.00%
Van		0	0	0	0	0.00%

Table 4: Summary Data (Vehicle Class)

BEV						
		Number of Manufacturers	Number of Models	Average Generation of Models	2021 Sales (North America)	2021 In Class Market Share (North America)
LD Sedan		9	9	2	245785	6.78%
BMW			1	3	1653	0.05%
Chevrolet			1	3	29502	0.81%
Kia			1	2	9463	0.26%

MINI		1	1	8557	0.24%
Nissan		1	3	15460	0.43%
Porsche		1	3	9520	0.26%
Tesla		2	2	146570	4.04%
Volkswagen		1	2	5041	0.14%
Mercedes		1	1	443	0.01%
LD SUV	9	11	2	350853	3.86%
Hyundai		2	3	99136	1.09%
Audi		1	1	8732	0.10%
Tesla		2	1	176232	1.94%
Jaguar		1	1	1501	0.02%
Ford		1	2	31363	0.35%
Kia		1	1	10290	0.11%
Volkswagen		1	2	17282	0.19%
Volvo		1	2	6318	0.07%
Mercedes		1	0	0	0.00%
LD Pickup Truck	5	5	0	898	0.03%
Ford		1	0	0	0.00%
GM		1	0	1	0.00%
Rivian		1	1	897	0.03%
Lordstown		1	0	0	0.00%
Chevrolet		1	0	0	0.00%
MD/HD Truck	15	29	1	219	0.02%
Volvo		6	1	30	0.00%
Daimler		3	0	0	0.00%
Peterbilt		3	0	0	0.00%
ELMS		1	0	0	0.00%
Kenworth		2	0	10	0.00%
Nikola		1	0	2	0.00%
Tesla		1	0	0	0.00%
BYD		4	2	103	0.01%

Mitsubishi		1	1	0	0.00%
Mercedes		1	0	0	0.00%
Lion		2	1	46	0.00%
DAF		1	0	0	0.00%
GreenPower		3	1	23	0.00%
Mack		1	0	0	0.00%
Navistar		1	1	5	0.00%
Van	11	13	0	1155	0.26%
BrightDrop		1	1	500	0.11%
ELMS		1	1	500	0.11%
Rivian		1	1	9	0.00%
Ford		1	0	0	0.00%
GM		1	0	0	0.00%
Arrival		1	0	0	0.00%
Volkswagen		1	0	0	0.00%
Canoo		1	0	0	0.00%
Cenntro Auto Group		2	0	0	0.00%
Lightning eMotors		2	1	146	0.03%
GreenPower		1	0	0	0.00%
FCV					
	Number of Manufacturers	Number of Models	Average Generation of Models	2021 Sales (North America)	2021 In Class Market Share (North America)
LD Sedan	1	1	2	2757	0.08%
Toyota		1	2	2757	0.08%
LD SUV	1	1	1	422	0.00%
Hyundai		1	1	422	0.00%
LD Pickup Truck	0	0	0	0	0.00%
MD/HD Truck	6	9	0	41	0.00%
Nikola		2	1	2	0.00%
Kenworth		1	0	0	0.00%

DAF		1	0	0	0.00%
Hyzon		3	1	39	0.00%
Hino		1	0	0	0.00%
Hyundai		1	0	0	0.00%
Van	0	0	0	0	0.00%

Table 5: Summary Data (Manufacturer)

BEV						
		Number of Manufacturers	Number of Models	Average Generation of Models	2021 Sales (North America)	2021 In Class Market Share (North America)
LD Sedan		9	9	2	245785	6.78%
BMW			1	3	1653	0.05%
	i3			3	1653	0.05%
Chevrolet			1	3	29502	0.81%
	BOLT			3	29502	0.81%
Kia			1	2	9463	0.26%
	Soul EV			2	9463	0.26%
MINI			1	1	8557	0.24%
	Cooper SE Electric			1	8557	0.24%
Nissan			1	3	15460	0.43%
	Leaf			3	15460	0.43%
Porsche			1	3	9520	0.26%
	Taycan			3	9520	0.26%
Tesla			2	2	146570	4.04%
	Model 3			1	134412	3.71%
	Model S			2	12158	0.34%
Volkswagen			1	2	5041	0.14%
	e-Golf			2	5041	0.14%
Mercedes			1	1	443	0.01%

	EQS			1	443	0.00%
LD SUV		9	11	2	350853	3.86%
Hyundai			2	3	99136	1.09%
	KONA			3	96510	1.06%
	IONIQ electric			2	2626	0.03%
Audi			1	1	8732	0.10%
	e-Tron			1	8732	0.10%
Tesla			2	1	176232	1.94%
	Model X			1	8305	0.09%
	Model Y			1	167927	1.85%
Jaguar			1	1	1501	0.02%
	I-Pace			1	1501	0.02%
Ford			1	2	31363	0.35%
	Mustang Mach-e			2	31363	0.35%
Kia			1	1	10290	0.11%
	Niro			1	10290	0.11%
Volkswagen			1	2	17282	0.19%
	ID.4			2	17282	0.19%
Volvo			1	2	6318	0.07%
	XC40 Electric			2	6318	0.07%
Mercedes			1	0	0	0.00%
	EQA			0	0	0.00%
LD Pickup Truck		5	5	0	898	0.03%
Ford			1	0	0	0.00%
	F-150 Lightning			0	0	0.00%
GM			1	0	1	0.00%
	Hummer EV			0	1	0.00%
Rivian			1	1	897	0.03%
	R1T			1	897	0.03%
Lordstown			1	0	0	0.00%
	Endurance			0	0	0.00%

Chevrolet			1	0	0	0.00%
	Silverado EV			0	0	0.00%
MD/HD Truck		15	29	1	219	0.02%
Volvo			6	1	30	0.00%
	FH Electric			1	6	0.00%
	FM Electric			1	6	0.00%
	FE Electric			1	6	0.00%
	FL Electric			1	6	0.00%
	FMX Electric			1	6	0.00%
	VNR Electric			2	0	0.00%
Daimler			3	0	0	0.00%
	Freightliner eCascadia			0	0	0.00%
	Freightliner eM2			0	0	0.00%
	FCCC MT50e			0	0	0.00%
Peterbilt			3	0	0	0.00%
	220EV			0	0	0.00%
	579EV			0	0	0.00%
	520EV			0	0	0.00%
ELMS			1	0	0	0.00%
	Urban Utility			0	0	0.00%
Kenworth			2	0	10	0.00%
	T680E			0	10	0.00%
	K270E			0	0	0.00%
Nikola			1	0	2	0.00%
	Tre BEV			0	2	0.00%
Tesla			1	0	0	0.00%
	Tesla Semi			0	0	0.00%
BYD			4	2	103	0.01%
	8TT			3	28	0.00%
	8R			1	25	0.00%
	6F			3	25	0.00%

	6R			1	25	0.00%
Mitsubishi			1	1	0	0.00%
	eCanter			1	0	0.00%
Mercedes			1	0	0	0.00%
	eActros			0	0	0.00%
Lion			2	1	46	0.00%
	6			1	23	0.00%
	8			1	23	0.00%
DAF			1	0	0	0.00%
	LF Electric			0	0	0.00%
GreenPower			3	1	23	0.00%
	EV Star CC			1	22	0.00%
	EV Star CC RHD			1	0	0.00%
	EV Star CC Cargo+			1	1	0.00%
Mack			1	0	0	0.00%
	LR Electric			0	0	0.00%
Navistar			1	1	5	0.00%
	International eMV			1	5	0.00%
Van		11	13	0	1155	0.26%
BrightDrop			1	1	500	0.11%
	Zevo 600			1	500	0.11%
ELMS			1	1	500	0.11%
	Urban Delivery			1	500	0.11%
Rivian			1	1	9	0.00%
	Commercial Van			1	9	0.00%
Ford			1	0	0	0.00%
	E-Transit			0	0	0.00%
GM			1	0	0	0.00%
	Ram Promaster			0	0	0.00%
Arrival			1	0	0	0.00%
	EV Van			0	0	0.00%

Volkswagen			1	0	0	0.00%
	Crafter EV			0	0	0.00%
Canoo			1	0	0	0.00%
	MPDV			0	0	0.00%
Cenntro Auto Group			2	0	0	0.00%
	Logistar 400			0	0	0.00%
	Logistar 200			0	0	0.00%
Lightning eMotors			2	1	146	0.03%
	F-59			1	68	0.02%
	T-350 HD			1	78	0.02%
GreenPower			1	0	0	0.00%
	EV Star Cargo			0	0	0.00%
FCV						
		Number of Manufacturers	Number of Models	Average Generation of Models	2021 Sales (North America)	2021 In Class Market Share (North America)
LD Sedan		1	1	2	2757	0.08%
	Toyota		1	2	2757	0.08%
	Mirai			2	2757	0.08%
LD SUV		1	1	1	422	0.00%
	Hyundai		1	1	422	0.00%
	NEXO			1	422	0.00%
LD Pickup Truck		0	0	0	0	0.00%
MD/HD Truck		6	9	0	41	0.00%
	Nikola		2	1	2	0.00%
	Tre FCEV			1	2	0.00%
	Two FCEV			0	0	0.00%
Kenworth			1	0	0	0.00%
	K370E			0	0	0.00%
DAF			1	0	0	0.00%

	XF H2			0	0	0.00%
Hyzon			3	1	39	0.00%
	Class 8			1	13	0.00%
	Econic Refuse			1	13	0.00%
	Drayage			1	13	0.00%
Hino			1	0	0	0.00%
	XL FCEV			0	0	0.00%
Hyundai			1	0	0	0.00%
	Xcient			0	0	0.00%
Van		0	0	0	0	0.00%

Table 6: Summary Data (Model)

Appendix B: Score Results

BEV					
	Number of Manufacturers	Number of Models	Average Generation of Models	2021 In Class Market Share (North America)	Average
LD Sedan	25.00%	4.89%	49.71%	7.02%	18.49%
LD SUV	22.50%	5.82%	53.22%	4.24%	17.47%
LD Pickup Truck	35.71%	17.24%	5.00%	0.03%	3.92%
MD/HD Truck	100.00%	35.37%	18.33%	0.02%	11.36%
Van	100.00%	76.47%	10.51%	0.26%	11.62%
FCV					
	Number of Manufacturers	Number of Models	Average Generation of Models	2021 In Class Market Share (North America)	Average
LD Sedan	2.78%	0.54%	43.90%	0.09%	11.20%
LD SUV	2.50%	0.53%	33.61%	0.01%	8.56%
LD Pickup Truck	0.00%	0.00%	0.00%	0.00%	0.00%
MD/HD Truck	60.00%	10.98%	9.17%	0.00%	5.84%
Van	0.00%	0.00%	0.00%	0.00%	0.00%

Table 9: Score Results (Vehicle Class)

BEV						
		Number of Manufacturers	Number of Models	Average Generation of Models	2021 In Class Market Share (North America)	Average
LD Sedan		25.00%	4.89%	49.71%	7.69%	18.92%
BMW			38.59%	65.85%	1.86%	24.73%
Chevrolet			38.59%	65.85%	33.04%	43.44%
Kia			38.59%	43.90%	10.66%	23.43%
MINI			38.59%	21.95%	9.64%	16.23%
Nissan			38.59%	65.85%	17.42%	34.07%
Porsche			38.59%	65.85%	10.73%	30.05%
Tesla			77.17%	32.93%	100.00%	77.60%

Volkswagen			38.59%	43.90%	5.68%	20.44%
Mercedes			38.59%	21.95%	0.50%	10.74%
LD SUV		22.50%	5.82%	53.22%	4.24%	17.47%
Hyundai			42.33%	84.03%	47.87%	58.16%
Audi			21.16%	33.61%	4.22%	14.73%
Tesla			42.33%	33.61%	85.09%	65.37%
Jaguar			21.16%	33.61%	0.72%	12.64%
Ford			21.16%	67.23%	15.14%	31.37%
Kia			21.16%	33.61%	4.97%	15.18%
Volkswagen			21.16%	67.23%	8.34%	27.29%
Volvo			21.16%	67.23%	3.05%	24.11%
Mercedes			21.16%	0.00%	0.00%	2.12%
LD Pickup Truck		35.71%	17.24%	5.00%	0.03%	3.92%
Ford			48.28%	0.00%	0.00%	4.83%
GM			48.28%	0.00%	0.00%	4.83%
Rivian			48.28%	25.00%	0.42%	12.58%
Lordstown			48.28%	0.00%	0.00%	4.83%
Chevrolet			48.28%	0.00%	0.00%	4.83%
MD/HD Truck		100.00%	35.37%	18.33%	0.02%	11.36%
Volvo			73.17%	29.17%	0.10%	16.13%
Daimler			36.59%	0.00%	0.00%	3.66%
Peterbilt			36.59%	0.00%	0.00%	3.66%
ELMS			12.20%	0.00%	0.00%	1.22%
Kenworth			24.39%	0.00%	0.03%	2.46%
Nikola			12.20%	0.00%	0.01%	1.22%
Tesla			12.20%	0.00%	0.00%	1.22%
BYD			48.78%	50.00%	0.33%	20.08%
Mitsubishi			12.20%	25.00%	0.00%	8.72%
Mercedes			12.20%	0.00%	0.00%	1.22%
Lion			24.39%	25.00%	0.15%	10.03%
DAF			12.20%	0.00%	0.00%	1.22%

GreenPower			36.59%	25.00%	0.07%	11.20%
Mack			12.20%	0.00%	0.00%	1.22%
Navistar			12.20%	25.00%	0.02%	8.73%
Van		100.00%	76.47%	10.51%	0.26%	11.62%
BrightDrop			47.06%	27.59%	0.90%	13.52%
ELMS			47.06%	27.59%	0.90%	13.52%
Rivian			47.06%	27.59%	0.02%	12.99%
Ford			47.06%	0.00%	0.00%	4.71%
GM			47.06%	0.00%	0.00%	4.71%
Arrival			47.06%	0.00%	0.00%	4.71%
Volkswagen			47.06%	0.00%	0.00%	4.71%
Canoo			47.06%	0.00%	0.00%	4.71%
Cenntro Auto Group			94.12%	0.00%	0.00%	9.41%
Lightning eMotors			94.12%	27.59%	0.26%	17.85%
GreenPower			47.06%	0.00%	0.00%	4.71%
FCV						
		Number of Manufacturers	Number of Models	Average Generation of Models	2021 In Class Market Share (North America)	Average
LD Sedan		2.78%	0.54%	43.90%	0.09%	11.20%
Toyota			19.57%	43.90%	3.11%	16.99%
LD SUV		2.50%	0.53%	33.61%	0.01%	8.56%
Hyundai			21.16%	33.61%	0.20%	12.32%
LD Pickup Truck		0.00%	0.00%	0.00%	0.00%	0.00%
MD/HD Truck		60.00%	10.98%	9.17%	0.00%	5.84%
Nikola			24.39%	12.50%	0.00%	6.19%
BYD			12.20%	0.00%	0.00%	1.22%
Kenworth			12.20%	0.00%	0.00%	1.22%
DAF			12.20%	0.00%	0.00%	1.22%
Hyzon			36.59%	25.00%	0.03%	11.18%

Hino			12.20%	0.00%	0.00%	1.22%
Hyundai			12.20%	0.00%	0.00%	1.22%
Van		0.00%	0.00%	0.00%	0.00%	0.00%

Table 10: Score Results (Manufacturer)

BEV						
		Number of Manufacturers	Number of Models	Average Generation of Models	2021 In Class Market Share (North America)	Average
LD Sedan		25.00%	4.89%	49.71%	7.69%	18.92%
BMW			38.59%	65.85%	1.86%	24.73%
	i3			65.85%	9.52%	32.05%
Chevrolet			38.59%	65.85%	55.80%	57.09%
	BOLT			65.85%	100.00%	86.34%
Kia			38.59%	43.90%	10.66%	23.43%
	Soul EV			43.90%	54.50%	50.26%
MINI			38.59%	21.95%	9.64%	16.23%
	Cooper SE Electric			21.95%	49.28%	38.35%
Nissan			38.59%	65.85%	17.42%	34.07%
	Leaf			65.85%	89.04%	79.76%
Porsche			38.59%	65.85%	10.73%	30.05%
	Taycan			65.85%	54.83%	59.24%
Tesla			77.17%	32.93%	100.00%	77.60%
	Model 3			21.95%	100.00%	68.78%
	Model S			43.90%	70.02%	59.57%
Volkswagen			38.59%	43.90%	5.68%	20.44%
	e-Golf			43.90%	29.03%	34.98%
Mercedes			38.59%	21.95%	0.50%	10.74%
	EQS			21.95%	1.02%	9.39%
LD SUV		22.50%	5.82%	53.22%	4.24%	17.47%
Hyundai			42.33%	84.03%	47.87%	58.16%
	KONA			100.00%	100.00%	100.00%

	IONIQ electric			67.23%	5.99%	30.49%
Audi			21.16%	33.61%	4.22%	14.73%
	e-Tron			33.61%	19.92%	25.40%
Tesla			42.33%	33.61%	85.09%	65.37%
	Model X			33.61%	18.95%	24.81%
	Model Y			33.61%	100.00%	73.45%
Jaguar			21.16%	33.61%	0.72%	12.64%
	I-Pace			33.61%	3.42%	15.50%
Ford			21.16%	67.23%	15.14%	31.37%
	Mustang Mach-e			67.23%	71.55%	69.82%
Kia			21.16%	33.61%	4.97%	15.18%
	Niro			33.61%	23.48%	27.53%
Volkswagen			21.16%	67.23%	8.34%	27.29%
	ID.4			67.23%	39.43%	50.55%
Volvo			21.16%	67.23%	3.05%	24.11%
	XC40 Electric			67.23%	14.41%	35.54%
Mercedes			21.16%	0.00%	0.00%	2.12%
	EQA			0.00%	0.00%	0.00%
LD Pickup Truck		35.71%	17.24%	5.00%	0.03%	3.92%
Ford			48.28%	0.00%	0.00%	4.83%
	F-150 Lightning			0.00%	0.00%	0.00%
GM			48.28%	0.00%	0.00%	4.83%
	Hummer EV			0.00%	0.00%	0.00%
Rivian			48.28%	25.00%	0.42%	12.58%
	R1T			25.00%	0.86%	10.52%
Lordstown			48.28%	0.00%	0.00%	4.83%
	Endurance			0.00%	0.00%	0.00%
Chevrolet			48.28%	0.00%	0.00%	4.83%
	Silverado EV			0.00%	0.00%	0.00%
MD/HD Truck		100.00%	35.37%	18.33%	0.02%	11.36%
Volvo			73.17%	29.17%	0.10%	16.13%

	FH Electric			25.00%	0.04%	10.02%
	FM Electric			25.00%	0.04%	10.02%
	FE Electric			25.00%	0.04%	10.02%
	FL Electric			25.00%	0.04%	10.02%
	FMX Electric			25.00%	0.04%	10.02%
	VNR Electric			50.00%	0.00%	20.00%
Daimler			36.59%	0.00%	0.00%	3.66%
	Freightliner eCascadia			0.00%	0.00%	0.00%
	Freightliner eM2			0.00%	0.00%	0.00%
	FCCC MT50e			0.00%	0.00%	0.00%
Peterbilt			36.59%	0.00%	0.00%	3.66%
	220EV			0.00%	0.00%	0.00%
	579EV			0.00%	0.00%	0.00%
	520EV			0.00%	0.00%	0.00%
ELMS			12.20%	0.00%	0.00%	1.22%
	Urban Utility			0.00%	0.00%	0.00%
Kenworth			24.39%	0.00%	0.03%	2.46%
	T680E			0.00%	0.06%	0.04%
	K270E			0.00%	0.00%	0.00%
Nikola			12.20%	0.00%	0.01%	1.22%
	Tre BEV			0.00%	0.01%	0.01%
Tesla			12.20%	0.00%	0.00%	1.22%
	Tesla Semi			0.00%	0.00%	0.00%
BYD			48.78%	50.00%	0.33%	20.08%
	8TT			75.00%	0.18%	30.11%
	6F			75.00%	0.16%	30.10%
	6R			25.00%	0.16%	10.10%
Mitsubishi			12.20%	25.00%	0.00%	8.72%
	eCanter			25.00%	0.00%	10.00%
Mercedes			12.20%	0.00%	0.00%	1.22%
	eActros			0.00%	0.00%	0.00%

Lion			24.39%	25.00%	0.15%	10.03%
	6			25.00%	0.15%	10.09%
	8			25.00%	0.15%	10.09%
DAF			12.20%	0.00%	0.00%	1.22%
	LF Electric			0.00%	0.00%	0.00%
GreenPower			36.59%	25.00%	0.07%	11.20%
	EV Star CC			25.00%	0.14%	10.08%
	EV Star CC RHD			25.00%	0.00%	10.00%
	EV Star CC Cargo+			25.00%	0.01%	10.00%
Mack			12.20%	0.00%	0.00%	1.22%
	LR Electric			0.00%	0.00%	0.00%
Navistar			12.20%	25.00%	0.02%	8.73%
	International eMV			25.00%	0.03%	10.02%
Van		100.00%	76.47%	10.51%	0.26%	11.62%
BrightDrop			47.06%	27.59%	0.90%	13.52%
	Zevo 600			27.59%	1.92%	12.19%
ELMS			47.06%	27.59%	0.90%	13.52%
	Urban Delivery			27.59%	1.92%	12.19%
Rivian			47.06%	27.59%	0.02%	12.99%
	Commercial Van			27.59%	0.03%	11.06%
Ford			47.06%	0.00%	0.00%	4.71%
	E-Transit			0.00%	0.00%	0.00%
GM			47.06%	0.00%	0.00%	4.71%
	Ram Promaster			0.00%	0.00%	0.00%
Arrival			47.06%	0.00%	0.00%	4.71%
	EV Van			0.00%	0.00%	0.00%
Volkswagen			47.06%	0.00%	0.00%	4.71%
	Crafter EV			0.00%	0.00%	0.00%
Canoo			47.06%	0.00%	0.00%	4.71%
	MPDV			0.00%	0.00%	0.00%
Cenntro Auto Group			94.12%	0.00%	0.00%	9.41%

	Logistar 400			0.00%	0.00%	0.00%
	Logistar 200			0.00%	0.00%	0.00%
Lightning eMotors		94.12%		27.59%	0.26%	17.85%
	F-59			27.59%	0.26%	11.19%
	T-350 HD			27.59%	0.30%	11.21%
GreenPower		47.06%		0.00%	0.00%	4.71%
	EV Star Cargo			0.00%	0.00%	0.00%
FCV						
		Number of Manufacturers	Number of Models	Average Generation of Models	2021 In Class Market Share (North America)	Average
LD Sedan		2.78%	0.54%	43.90%	0.09%	11.20%
	Toyota		19.57%	43.90%	3.11%	16.99%
	Mirai			43.90%	15.88%	27.09%
LD SUV		2.50%	0.53%	33.61%	0.01%	8.56%
	Hyundai		21.16%	33.61%	0.20%	12.32%
	NEXO			33.61%	0.96%	14.02%
LD Pickup Truck		0.00%	0.00%	0.00%	0.00%	0.00%
MD/HD Truck		60.00%	10.98%	9.17%	0.00%	5.84%
	Nikola		24.39%	12.50%	0.00%	6.19%
	Tre FCEV			25.00%	0.01%	10.01%
	Two FCEV			0.00%	0.00%	0.00%
	BYD		12.20%	0.00%	0.00%	1.22%
	8R			25.00%	0.16%	10.10%
	Kenworth		12.20%	0.00%	0.00%	1.22%
	K370E			0.00%	0.00%	0.00%
	DAF		12.20%	0.00%	0.00%	1.22%
	XF H2			0.00%	0.00%	0.00%
	Hyzon		36.59%	25.00%	0.03%	11.18%
	Class 8			25.00%	0.08%	10.05%

	Econic Refuse			25.00%	0.08%	10.05%
	Drayage			25.00%	0.08%	10.05%
Hino			12.20%	0.00%	0.00%	1.22%
	XL FCEV			0.00%	0.00%	0.00%
Hyundai			12.20%	0.00%	0.00%	1.22%
	Xcient			0.00%	0.00%	0.00%
Van		0.00%	0.00%	0.00%	0.00%	0.00%

Table 11: Score Results (Model)