Next Generation Manufacturing Canada

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CANADIAN AUTOMOTIVE SUPPLIER CAPABILITY AND EV VALUE CHAIN ANALYSIS

March, 2022

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Foreword

JAYSON MYERS, CEO

Canada is one of the many countries committed to transitioning from internal combustion engine to electric-powered, zero-emission vehicles by 2035. The internationally competitive nature of this market requires Canada to act quickly and strategically. Global market forecasts suggest that electric vehicles (EVs) will account for almost 11 percent of global sales by 2025 and up to 50 percent by 2030. Canada has the opportunity to be a major global player in this transformation and take advantage of all the economic spin-offs that would entail.

Gasoline and diesel-powered internal combustion engines (ICEs) have historically been the powertrain of choice for passenger and commercial vehicles. However, due to stricter regulation, increased competition and changing customer demand, many original equipment manufacturers (OEMs) have recently reconsidered their current vehicle and powertrain offerings.

Emission regulations set by national and local authorities, tighter fleet CO2-emission standards, zero emission vehicle (ZEV) mandates and climate targets such as the Paris Agreement are the main drivers forcing the automotive industry to rethink how vehicles are powered. The new blend of powertrain technologies consists of full and mild hybrids, plug-in hybrids, battery electric vehicles, and fuel cell electric vehicles (FCEV). This transformation presents obstacles and opportunities not only for OEMs but also for powertrain and component suppliers.

JOHN LAUGHLIN, CTO

We are delighted to share this study with the automotive industry in Canada. The report focuses on the factors driving the transition to electric vehicles, the composition of Canada's automotive parts supplier industry, and the development of electric vehicle (EV) technologies and markets. Our aim with this report is to provide industry with analysis and insights that highlight Canada's opportunities to build upon its world-class research and manufacturing capabilities to develop new value chains to meet the shift to zero-emission vehicles.

Key highlights from this report demonstrate the benefits of rapidly building new Canadian EV value chains. This is a challenge - one that industry and all levels of government have demonstrated that they are willing and able to meet. Announcements from Ford, Honda, BASF, General Motors, and Stellantis and LG confirm Canada's intention to lead in the global transition to EVs. This is an outcome of collaboration across industry and government combined with significant investments in innovative manufacturing technologies.

NGen's project portfolio further demonstrates that companies throughout the value chain and across the country are investing in new capabilities and advanced manufacturing. Projects across the portfolio also serve as examples of Canada's environmental and socially responsible manufacturing advantage. These elements position Canada as a world leader in innovation and advanced manufacturing. NGen is committed to working with our research, technology, manufacturing, and public sector partners to capitalize on the opportunities highlighted in this report and to provide sustainable benefits for Canadians.

Disclaimer

The study is based on publicly and non-publicly available information, which has not been independently verified by PCCL or any other contributing party. Any assessments, assumptions and projections in this study solely represent the views of the authors. Neither PCCL, nor any of its affiliates, partners, or employees, provides any guarantee or warranty (express or implied) or assumes any responsibility or liability for any errors or omissions.

Note: This study builds upon the foundations of "Drive to Win" report, released by the Department of Innovation, Science and Economic Development (ISED) and the Ontario Ministry of Economic Development and Growth (MEDG), the "What We've Heard" and "Hydrogen Strategy for Canada" reports, which were released by Natural Resources Canada (NRCan) and "The Road Ahead" report of the House of Commons Standing Committee on Environment and Sustainable Development.

This study uses projections of North American production and powertrain mix from 2019 to 2030 based on IHS Markit data. Findings and conclusions are based on data from 2019 to avoid mis-interpretation due to the COVID-19 pandemic.

As the study was developed primarily using data from 2021, the Executive Order on Strengthening American Leadership in Clean Cars and Trucks by the Biden Administration to target 50% EV sales by 2032 is not reflected in the analysis.

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Abbreviations:

AGV .... Automated Guided Vehicles
AI .... Artificial Intelligence
APMA .... Automotive Parts Manufacturers Association
BEV .... Battery Electric Vehicle
CMMP .... Canadian Metals and Minerals Plan
CO2e .... CO2 Equivalent
CUSMA .... Canada-United States-Mexico-Agreement
DC .... Direct Current
DoE .... Department of Energy
EMC .... Electric Mobility Canada
EoL .... End-of-Life
EU .... European Union
EV .... Electric Vehicle
FCEV .... Fuel Cell Electric Vehicle
FDI .... Foreign Direct Investment
FPI .... Foreign Portfolio Investment
GHG .... Green House Gas
HEV .... Hybrid Electric Vehicle
HV .... High Voltage
ICE .... Internal Combustion Engine
ICEV .... Internal Combustion Engine Vehicle
IPCEI .... Important Project of Common European Interest
ISED .... Department of Innovation, Science and Economic Development
KPI .... Key Performance Indicator
LDV .... Light-duty Vehicle
LEV .... Low Emission Vehicle
LFP .... Lithium Iron Phosphate
MEDG .... Ontario Ministry of Economic Development and Growth
MHCV .... Medium- and Heavy-duty Commercial Vehicle
MSRP .... Manufacturer´s Suggested Retail Price
NAICS .... North American Industrial Classification System
NMC .... Nickel-Manganese-Cobalt
NRC .... National Research Council
NRCan .... Natural Resources Canada
OEE .... Overall Equipment Efficiency
OEM .... Original Equipment Manufacturer
PCCL .... Porsche Consulting Canada Ltd.
PHEVs .... Plug-In Hybrid Electric Vehicles
R&D .... Research & Development
RVC .... Regional Value Content
SME .... Small and Medium-Sized Enterprises
StatCan .... Statistics Canada
TCO .... Total Cost of Ownership
USMCA .... United States-Mexico-Canada Agreement
ZEV .... Zero-emission Vehicle

Preface

Executive Summary

Within 15 years, global automakers will transition most of their production away from internal combustion engine vehicles (ICEVs) to electric vehicles (EVs).

The transition to electric vehicles (EVs) represents the most fundamental transformation in the automotive industry in over a century. For Canada, the transition to EVs represents a once-in-a-lifetime opportunity to grow an industry that has long been vital to the nation's economic well-being. It also represents an opportunity to build on Canada's record of environmental governance, leverage the advantages of our low carbon electricity, and leverage our research, technological, and industrial strengths to become a global leader in EV technologies.

Significant innovation, investment, and commercial opportunities lie ahead throughout the EV value chain, from mineral extraction and hydrogen production, to refining, and processing, to battery manufacturing, to motors and powertrain, electronics and parts production, to final vehicle assembly.

Next Generation Manufacturing Canada (NGen), Porsche Consulting, the Trillium Network for Advanced Manufacturing, and the Automotive Parts Manufacturers' Association (APMA) have undertaken this collaborative study to better understand the opportunities that the transition to EVs affords Canadian industry and the trends that are likely to shape the future of Canada's automotive sector. It is one of several important initiatives our organizations are leading in support of Canada's EV sector, including NGen's EV funding challenge, the APMA's Project Arrow, and a web-based application developed by NGen and the Trillium Network that maps Canada's EV ecosystem.

The automotive industry is a critical component of Canada's economy. It contributes over $16 billion to GDP and employs more than 130,000 people in ten passenger and light-duty vehicle assembly plants in Ontario, several bus and truck manufacturing facilities in Quebec, Ontario, and Manitoba, and a well-developed network of automotive parts and components suppliers.

This network of suppliers is dominated by large, globally-competitive companies (the ten largest account for approximately half of all revenue in this segment), and the broader supply chain is closely integrated with the automotive industry in the United States and Mexico. Powertrain suppliers, almost all of which currently focus on manufacturing parts and components for internal combustion engines, represent the largest segment of this industry. It will be especially important to support these suppliers during the transition to EVs.

Beyond manufacturing, Canada is the location of a growing network of private companies and publicly-funded organizations that engage in automotive- and automobility-related R&D. Much of this R&D is focused on next generation low emission technologies, including EV batteries, fuel cells, and lightweight materials.

The automotive industry in Canada has not been immune to the headwinds associated with the COVID-19 pandemic and the shifting geo-political landscape. Despite these challenges, there is a great deal of reason for optimism about the future of the sector. Toyota, the largest vehicle producer in Canada, has built hybrid vehicles at their Ontario-based assembly plants for several years and will continue to upgrade their facilities moving forward. Ford and General Motors recently announced EV mandates for their Canadian assembly plants and have begun the process of planning and retooling those facilities. Honda will begin upgrading its Canadian assembly plants in order to produce hybrid vehicles as a first step to full electrification later this year. Five bus manufacturing facilities currently produce electrified models, with plans to grow. Tesla recently invested in battery equipment production facilities near Toronto and in an R&D facility in Halifax. Britishvolt and the Canadian-owned StromVolt have announced their intention to build battery manufacturing facilities in Quebec. And in the recent weeks, BASF and General Motors have announced plans to produce battery materials in Quebec, while Stellantis and LG Energy Solution have announced a joint venture that will establish a battery manufacturing plant in Windsor, Ontario. The latter is among the largest and most transformative investments for the automotive industry in Canadian history.

These investments and clusters of R&D activity represent the growing number of success stories related to Canada's automotive industry and its transition to EVs. Canada can, and should, continue to leverage existing competitive advantages to secure additional investments across the EV supply chain. These competitive advantages include the country's existing automotive footprint, which encompasses the aforementioned assembly plants as well as the global headquarters of companies like Magna, Linamar, Martinrea, Multimatic, Woodbridge Foam, Ballard Power Systems, Lion Electric, and the New Flyer Group.

Canada has plentiful reserves of minerals like nickel, lithium, graphite, and cobalt, which are critical for battery production. Meanwhile, our supply of low carbon electricity offers a compelling reason for investments on the part of companies looking to process those minerals in Canada, locate battery production here, or manufacture electric vehicles, parts, and components in Canada, enabling them to minimize their carbon footprint. Plans to develop and leverage these domestic mineral resources are outlined in the Government of Canada's '**Mines to Mobility'** report, Ontario's **Critical Minerals Strategy**, and Quebec's **Plan for the Development of Critical and Strategic Minerals**.

Canada has other competitive advantages as well. Our highly skilled and educated workforce, publicly-funded universities and colleges, and immigration practices offer automakers, mining companies, battery producers, and parts manufacturers ready access to talented personnel. Our close trading relationship with the United States is governed by the USMCA and its favourable provisions for North American automotive content. Finally, Canada's stable and democratic political environment and responsible system of corporate governance support environmental, social, and economic sustainability in a manner that governments in many other countries do not.

Canada's EV Landscape: The Shift to Electric Vehicles

Consumer Demand	Climate Change	Legislation and Politics	Technological Progress	Total Cost of Ownership (TCO)	Infrastructure Development
Consumers are demanding policies and solutions to fight climate change	6% of worldwide CO_2 originates from fossil fuel burning vehicles	To prevent climate change, legislation is driving OEMs to reduce vehicle CO_2 emissions	OEMs have significantly increased the number of electric models available	TCO for BEVs is approaching parity with ICE vehicles	Charging infrastructure is becoming increasingly available

Figure 1: Forces accelerating the switch to Electric Mobility

Six interdependent factors are driving the shift away from ICEVs and towards EVs (Figure 1):

1. Consumer Demand
2. Climate Change
3. Legislation and Politics
4. Technological Innovation
5. Total Cost of Ownership
6. Infrastructure Development

1. Consumer Demand

Although EVs occupied a niche in the automotive market until only recently, their widespread adoption is being enabled by consumer demand for policies and solutions to mitigate the negative impacts of climate change. Consumers are both benefiting from this shift (i.e. by reduced cost of ownership) and driving it (i.e. lobbying for better charging infrastructure), creating a positive feedback loop.

2. Climate Change

Climate change is one of the most important public policy issues today, and governments and industry stakeholders are working to identify strategic levers to overcome the corresponding challenges. The Paris Agreement is perhaps the best-known example of such a lever, with 195 countries having ratified the agreement.

As a signatory to the Paris Agreement, Canada has committed to a 30 percent reduction in greenhouse gas emissions by 2030 compared to 2005 levels. These efforts aim to limit average global temperature increases to no more than 2°C compared to pre-industrial levels.

In Canada, road transportation accounted for 25 percent of total greenhouse gas emissions (measured in terms of CO_2-equivalent or CO_2e) in 2019. Reducing these emissions is an important component of achieving regulatory commitments and fighting climate change.

3. Legislation and Governance

As the transition towards EVs accelerates, countries are setting timelines to phase out the sale of new ICEVs, or moving existing timelines forward. While regulations differ across countries in scale and scope, over 20 - including Canada, Spain, France, and the United Kingdom - have established dates whereby the sale of new ICEVs (and in some cases, plug-in hybrid vehicles) must stop (Figure 2).

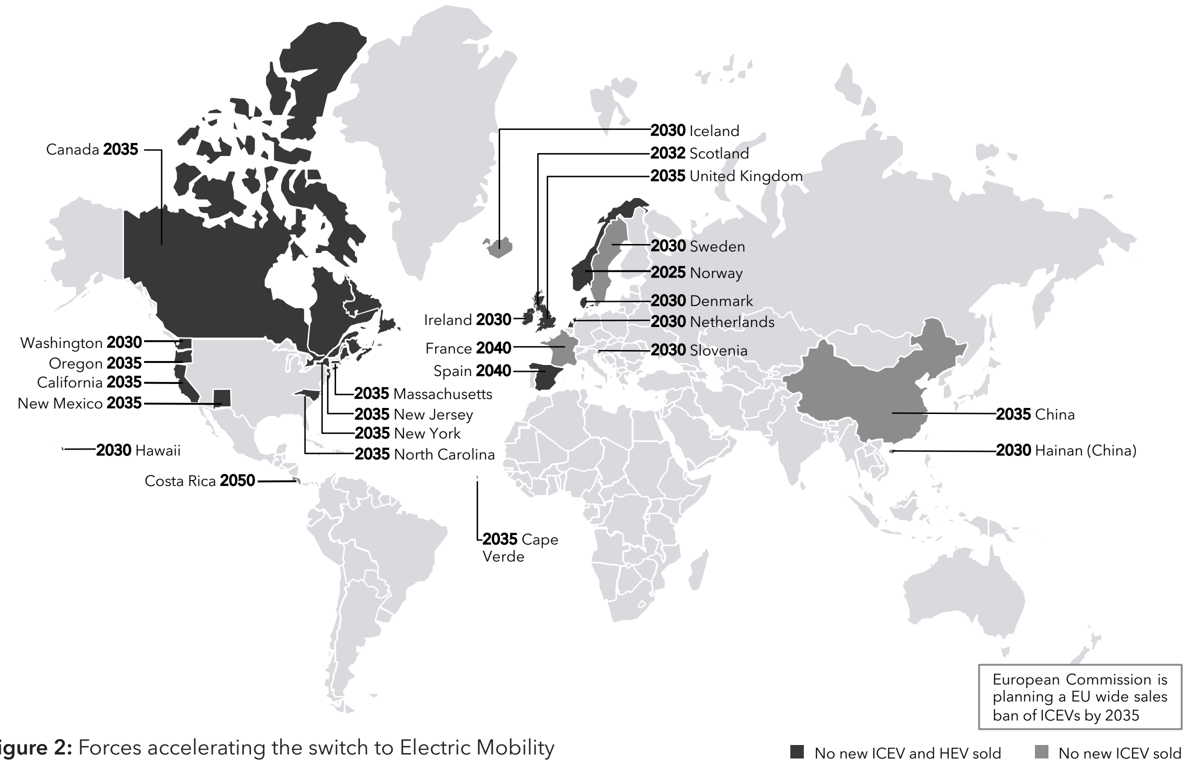


Figure 2: Forces accelerating the switch to Electric Mobility

Canada plans to phase out the sale of most new ICEVs by 2035. The United States federal government has not set such a date, although California, which has historically set the pace for progressive emissions regulations in North America, plans to phase out the sale of new ICEVs by 2035, with 13 other states following suit. Together, these states represent approximately 30 percent of vehicle sales in the United States.

The European Union has also announced plans to phase out the sale of new ICEVs across its member states by 2035, with some countries establishing their own deadlines. China, for its part, has not set an overall phase out date but plans for all vehicle sales from 2035 on to be electrified models.

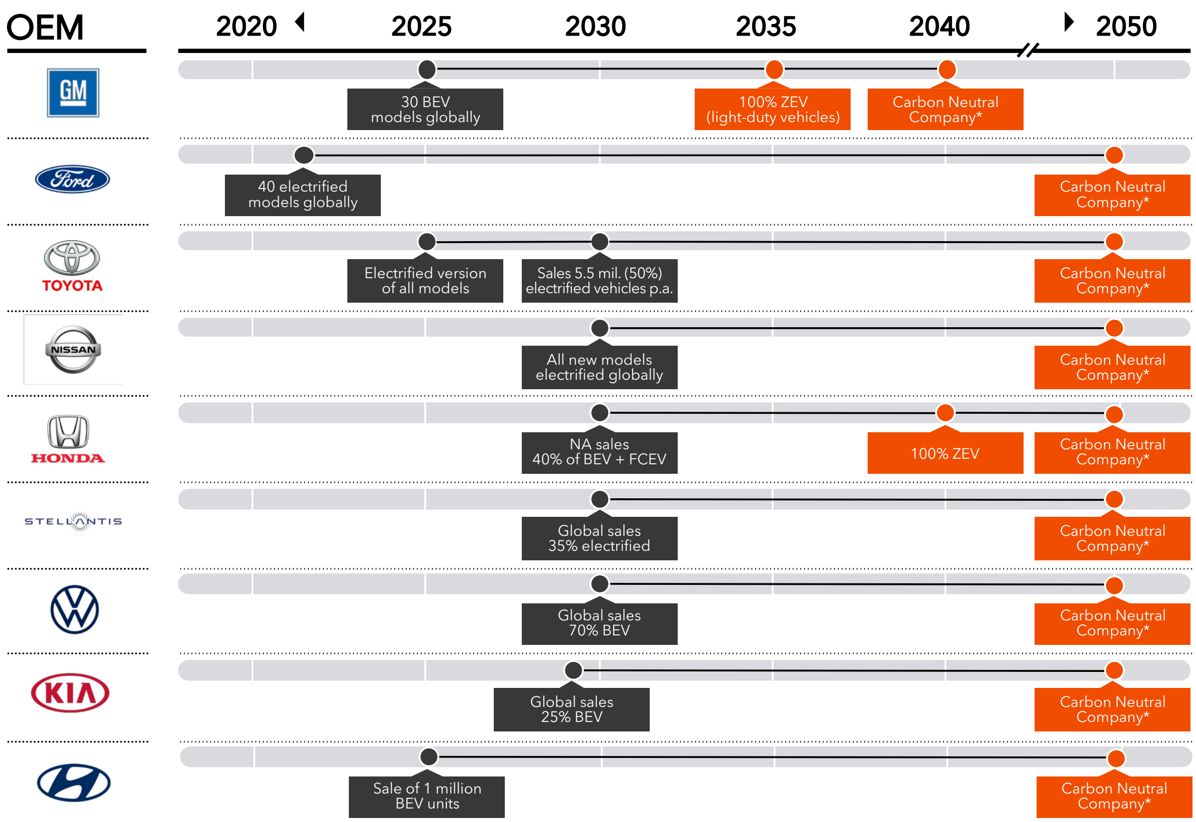
4. Technological Innovation

Technological advances are making EVs more attractive to consumers as well. This is especially the case with Battery-powered Electric Vehicles (BEVs). Automakers have announced 290 new BEV model launches through 2025. The range of most of these models will be between 300 and 500 km, with battery capacities between 80 and 100 kWh. This is a decisive factor, as one of the major concerns for buyers is the limited range of and infrastructure supporting BEVs. With zero-emission mobility forming the cornerstone of automakers' product roadmaps, customers will have an abundance of appealing, practical, and affordable EVs to choose from in the coming years.

As shown in Figure 3, product decisions and regulatory catalysts have led eight automakers to commit to becoming CO2 neutral by 2050. General Motors (GM), for example, plans to phase out ICEV sales by 2035, while the Volkswagen Group has set internal goals to reduce the average lifetime CO2e emissions of its newly produced vehicles by 30% through 2025. This will ultimately enable carbon-neutrality by 2050 for those automakers. By 2030, EVs are expected to account for 45 percent of all new light-duty vehicle sales, globally.

5. Total Cost of Ownership

Until recently only a small number of mass-produced BEVs (like the Nissan Leaf and Chevrolet Volt) or luxury model BEVs (like the Tesla Model S) have been available to customers. The availability of additional mass-produced BEVs, such as the Tesla Model 3 and Volkswagen ID.4, will help lower consumer barriers to entering the BEV market.



* Commitment to targets of Paris Agreement, which aims to achieve a climate-neutral society by 2050
Source: Press releases of OEMs

Figure 3: Overview of global OEM ICEV exit strategies.

As battery, manufacturing, and assembly costs decrease, total cost of ownership begins to shift in favour of BEVs. The total cost of ownership advantage is primarily due to the lower cost of electricity when compared to the cost of gasoline or diesel and to lower maintenance costs for BEVs. Studies show that the residual value of a BEV is similar to that of a comparable ICEV. Lower total cost of ownership is a major factor in facilitating widespread BEV adoption.

6. Infrastructure Development

Mass-market adoption of EVs has lagged due to the limited availability of adequate charging and hydrogen-refueling infrastructure. In the first quarter of 2021, approximately 50,000 charging stations and 54 hydrogen-refueling stations were in operation in North America, compared to 175,000 gas stations. The limited availability of hydrogen-refueling stations has been a major barrier in the adoption of Fuel Cell Electric Vehicles (FCEVs). That said, the development of charging infrastructure for BEVs and Plug-in Hybrid Electric Vehicles (PHEVs) is accelerating with private sector initiatives led by Tesla, ChargePoint, Blink Charging, Electrify America/Canada, and FLO. U.S. President Joe Biden recently pledged to build 500,000 EV charging stations by 2030, significantly increasing coverage across the country. As EV charging infrastructure expands, governments and utility providers will also need to ensure that power generation and distribution systems can support this shift. Suffice to say, the development of a reliable and widely accessible EV infrastructure will support the transition to EVs in North America.

North American Automotive
Sales and Manufacturing

75% **of North American light-duty vehicles sold in 2025 will be SUVs and Pickup trucks**

Total vehicle volume will return to pre-Covid-19 levels in 2025 and stagnate until 2030

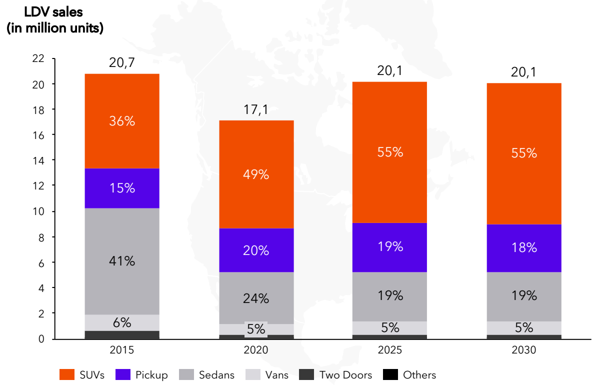


Figure 4: North American LDV sales (2015-2030)

Light-Duty Vehicle Sales

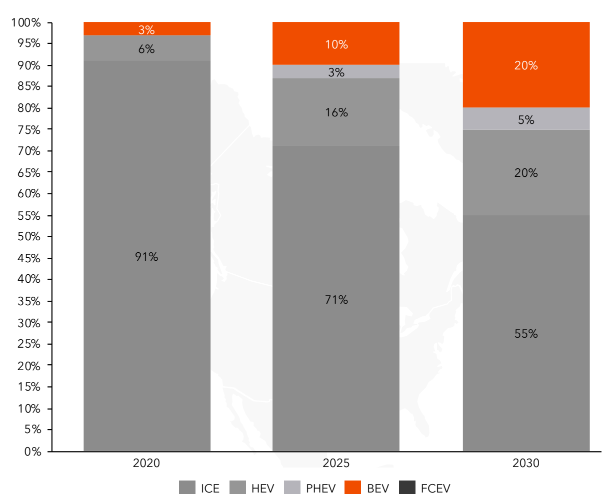
Annual light-duty vehicle sales in North America averaged just over 20 million between 2015 and 2019 (see Figure 4). New vehicle sales fell by over 3 million in 2020 as a result of the COVID-19 pandemic, but the market is expected to rebound and remain stable at around 20 million in new vehicle sales annually through 2030.

The share of various powertrain technologies, however, will undergo a significant shift over that period. As Figure 5 shows, the ICEV market share is projected to decrease from 91 percent in 2020 to 22 percent in 2035, while the share of BEV sales will increase from 3 percent in 2020 to twenty percent in 2030. Forecasts beyond 2030 are less reliable, but we expect the BEV market share to exceed 40 percent, with all electrified powertrains accounting for 78 percent of the market by 2035. This growth will be driven by the impact of regulations that restrict the sale and use of ICEVs.

This shift is, of course, dependent on automakers making drastic changes to their product lines and shifting production away from ICEVs and towards EVs.

Light-Duty Vehicle Manufacturing

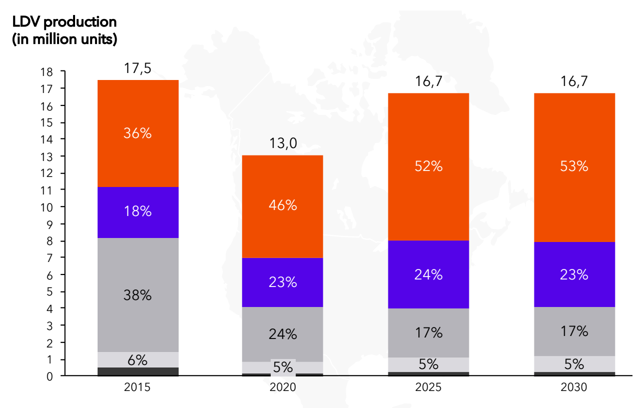
Over 17 million of the approximately 20 million vehicles sold in North America each year are manufactured in the region. Currently, there is a total installed manufacturing capacity (the number of vehicles that can be produced when assembly plants operate at or near maximum capacity) of 20 million units per year across 78 North American assembly plants. Cur-



Source: IHS Markit, Porsche Consulting

Figure 5: North American LDV market share by powertrain (2020-2030)

16.7 **million light-duty passenger vehicles will be produced annually until 2030**



Source: IHS Markit, Porsche Consulting

Figure 6: North American LDV production by country (2015-2030)

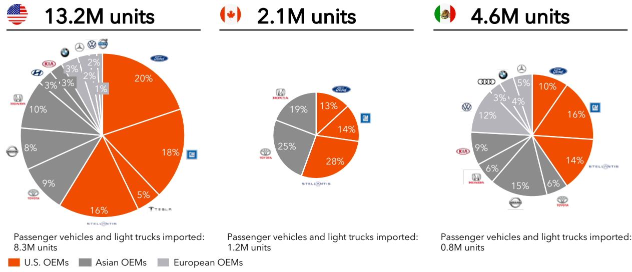


Figure 7: North American LDV production capacities by country and OEM

rent plant utilization rates stand around 85 percent.

Figure 6 shows that annual North American vehicle production declined from 17.5 million units in 2015 to 13 million units in 2020. Most of this decline was related to COVID-19. Some further decline is anticipated in 2021 due to COVID-19 and shortages of semiconductors. However, these are temporary factors and annual North American vehicle production is expected to increase and stabilize at around 16.7 million units through 2030. This is closely aligned with the sales trends mentioned above.

In Canada, installed annual light-duty vehicle manufacturing capacity is approximately 2.1. million units (see Figure 7). Annual vehicle production in 2021 is forecasted to be approximately 1.2 million units, representing a utilization rate of 60 percent across 10 assembly plants. All these assembly plants are located in southern Ontario, close to automakers and suppliers located in the U.S. Midwest (Figure 8).

Currently, only a fraction of current Canadian production capacity has been leveraged for EV manufacturing. Canadian assembly plants produced approximately 80,000 plug-in hybrid electric vehicles (PHEVs) and hybrid-electric vehicles (HEVs) in 2020. The Lexus R450h, Toyota RAV4, and Chrysler Pacifica are the only electrified light-duty vehicles currently produced in Canada. A large majority of these vehicles are exported to the US, while most of the remainder are sold in Canada. Very few are sold outside of North America. Strong North American demand for EVs is thus critical to the future development of the EV industry and supply chains in Canada.

Annual Canadian vehicle production dropped from 2.3 million units in 2015 to 1.5 million in 2020 - a downward trend that began in the early 2000s. In the late 1990s, Canada was the fifth largest vehicle producer in the world, coming in behind only the U.S., Japan, Germany, and France. Beginning in the early 2000s, however, Detroit-based automakers began to close assembly plants, and automakers have overlooked Canada as a site for greenfield investments (except for Toyota's Woodstock, Ontario assembly plant). This is due to higher labour costs and fewer trade agreements when compared to Mexico. Canada also lacks a domestically headquartered automaker and has been reluctant to try to compete with the incentives offered to automakers in the U.S. Since 2006, 11 new assembly plants were built in Mexico and seven were built in the U.S. (predominantly in the southeast), while only one was built in Canada (Toyota's 'West Plant' in Woodstock, Ontario).

Automakers have announced plans to manufacture new EV models - including BEVs and HEVs- at their existing Canadian assembly plants. Ford will begin assembling up to five BEV models at its Oakville assembly plant within the next five years, and both General Motors and Stellantis also plan to manufacture BEVs in Ontario within a similar timeframe. Honda recently announced the retooling of their assembly plant in Allison, Ontario to build the upcoming 2023 CR-V Hybrid

These investments will help catalyze Canada's transition to EV manufacturing, but they alone are not enough to transform the entire industry. Canada lags the U.S., China, and other leading automotive-producing countries in planned BEV production volumes. Industry stakeholders and governments at all levels

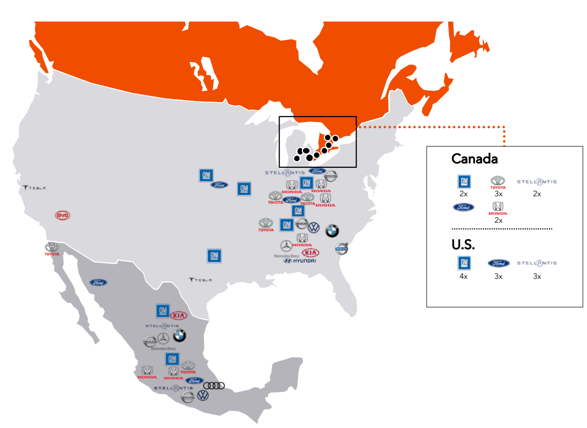


Figure 8: North American LDV OEM footprint

must work together to leverage opportunities to grow Canada's EV industry further. Otherwise, Canada risks losing these opportunities to other countries.

Medium- and Heavy-Duty Commercial Vehicles

Figure 9 shows that annual North American Medium- and Heavy-Duty Commercial Vehicle (MHCV) production was approximately 500,000 units in 2020, a 15 percent decrease when compared to 2015. This was largely the result of COVID-19. The market for MHCVs is expected to remain stable, with approximately 600,000 units - a mix of trucks (88 percent) and buses (12 percent) - produced annually by 2030. Canada's share of the North American market is projected to be four percent for both segments, which indicates that this industry sector will remain relatively small when compared to light-duty vehicle production.

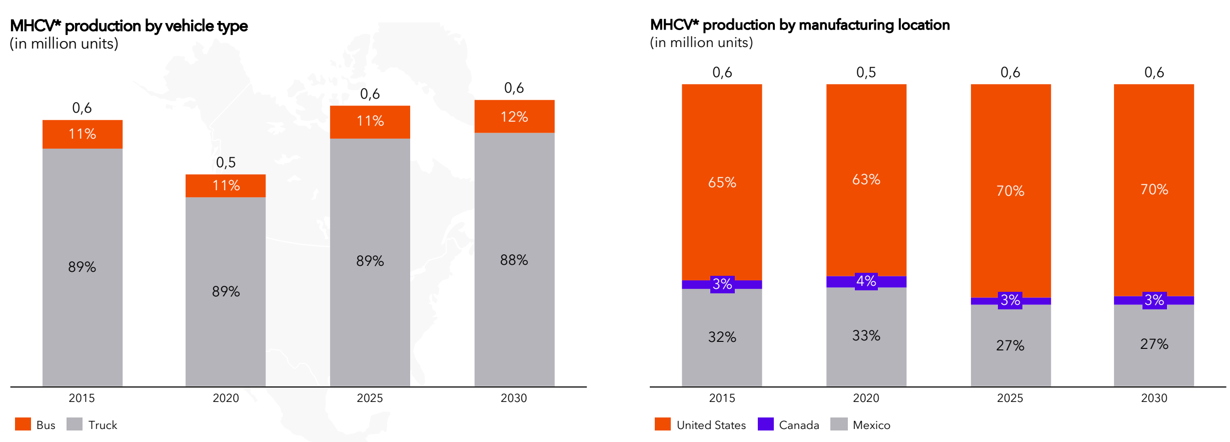
Despite relatively low production volumes, Canada's MHCV sector shows promise within the EV industry. Five EV models are currently being manufactured in Canada: Nova LFSe (Saint-Eustache, Québec), Nova LFS HEV (Saint-Eustache, Québec), Lion8 (Saint-Jérôme, Québec), BYD K9 (Newmarket, Ontario), and MCI J4500 Charge (Winnipeg, Manitoba).

Figure 10 shows that North American MHCV manufacturers are more geographically dispersed than light-duty vehicle manufacturers. Despite the low volumes and geographic distribution of production, MHCV (and related parts, components, and technologies) manufacturing remains economically important to several communities in Québec, Ontario, and Manitoba. MHCV manufacturing also represents an industry segment that includes Canadian-domiciled companies such as New Flyer Industries and the Lion Electric Company. Moreover, Canada's share within the electrified MHCV industry is 20 percent of the total market - significantly higher than its share of overall (ICEV plus EV) volume.

Figure 10: North American MHCV OEM landscape

Finally, although BEVs comprise less than one percent of the total MHCV powertrain mix, they are expected to reach 11 percent by 2030. The forecasted shift in the powertrain mix indicates that Canadian companies are leading electrification efforts within this industry sector and will be well-positioned to continue producing electrified MHCVs.

0.6 **Million medium- and heavy-duty commercials vehicles will be produced annually until 2030**



* Medium- and Heavy-Duty Vehicles
Source: IHS Markit, Statista, Porsche Consulting

Figure 9: North American MHCV production by vehicle type and country (2015-2030)

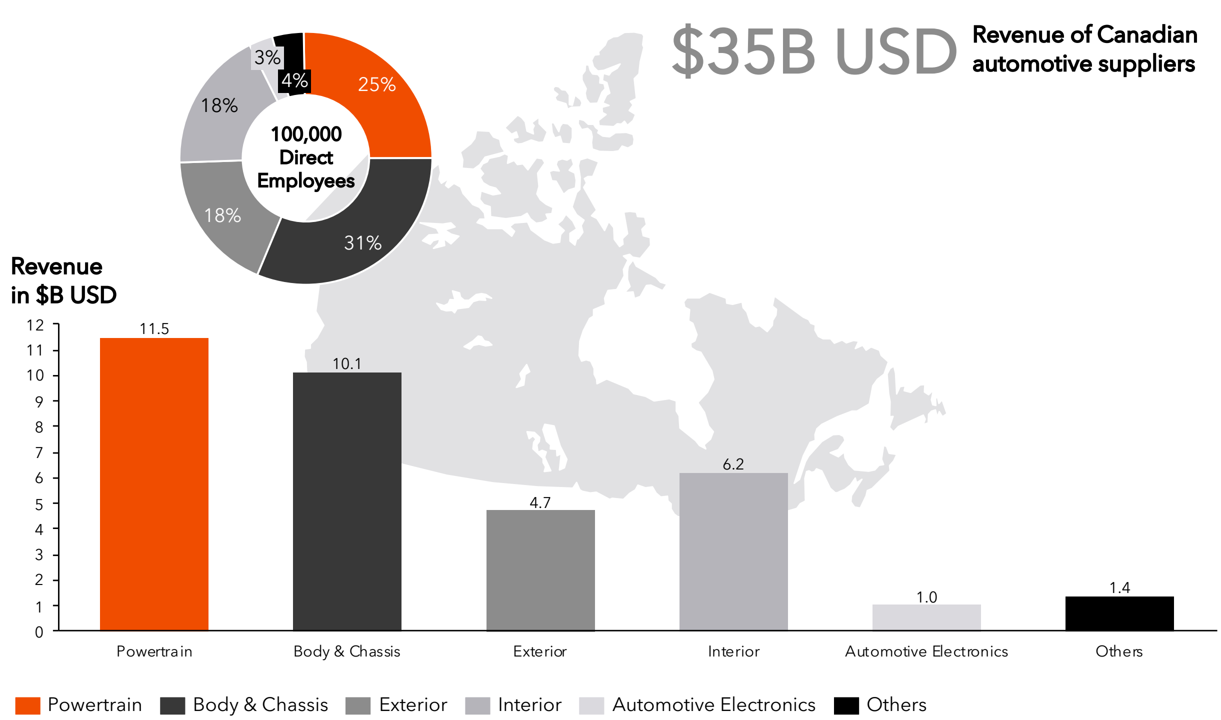
The Canadian Automotive Supplier Landscape

In order to understand the automotive supplier landscape, we collected data on 185 Canadian and internationally-owned parts and component suppliers that operate 417 manufacturing facilities in Canada. We estimate that this sample represents over 90 percent of the supply chain in terms of revenue and employment. Our findings, which are detailed in this chapter, suggest that certain segments of the supply chain - notably powertrain suppliers - are at risk during the shift towards electrification.

Automotive parts and components suppliers employ more than 100,000 people and generate US$35B in revenue. As such, they are a large and important component of the automotive industry in Canada and of Canada's advanced manufacturing ecosystem. The automotive parts and components industry includes facilities owned and operated by independent suppliers and by automakers themselves.

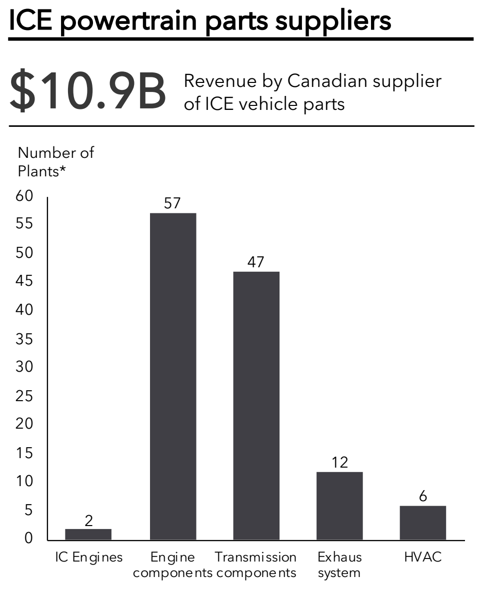
Powertrain suppliers, which employ more than 25,000 people and generate approximately US$10B in revenue, represent the largest segment of the automotive parts and components industry. These suppliers face heightened challenges associated with the shift to EVs when compared to other important segments of the supply chain, including Body & Chassis, Exterior, Interior, and Automotive Electronics (see Figure 11).

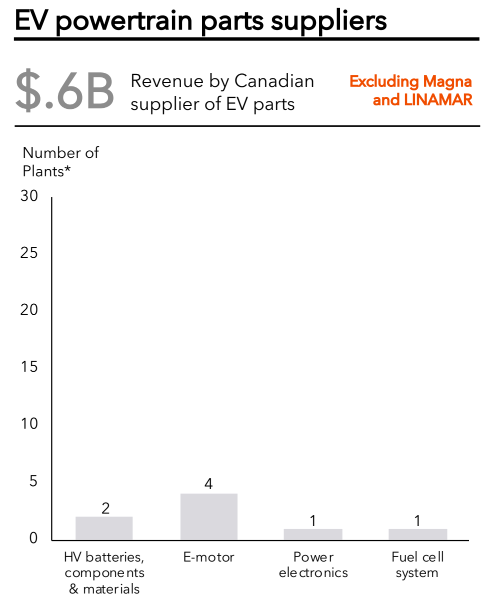
The manufacturing of engines, transmissions, and related components represents approximately 90 percent of all revenue generated within the powertrain supplier industry in Canada (Figure 12). EV powertrain component suppliers include internationally-owned companies such as Mitsui, Blue Solutions, and Dana. In total, EV powertrain component suppliers generate approximately US$600M annually - or less than five percent of all powertrain-related revenue - and many focus primarily on supplying parts and components for MHCVs. As the shift to EVs accelerates, established powertrain suppliers operating within Canada will need to re-evaluate their production capabilities.



Source: Porsche Consulting, Trillium

Figure 11: Total revenue by vehicle component category





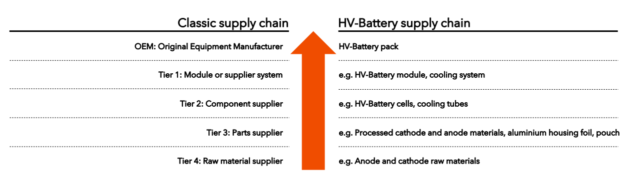
* Numbers used as indicators as a separation of product categories | ** Revenue for EV-only components could not be estimated and is therefore included in ICE powertrain revenue

Source: Trillium
Figure 12: Total revenue and number of plants by component for ICE & EV powertrains

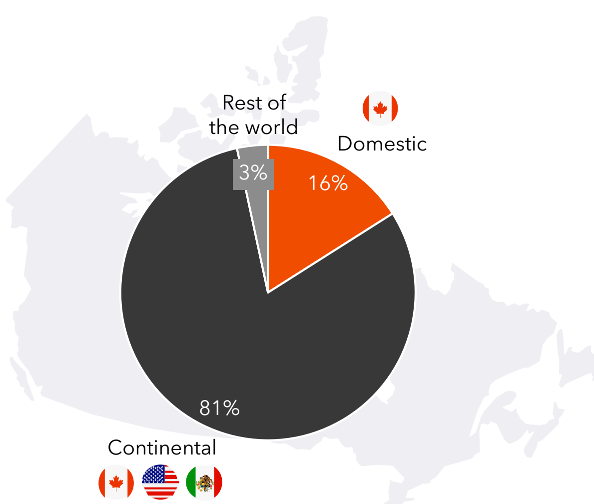
The majority of Canadian-made automotive parts and components are shipped within North America (Figure 13). More specifically:

- 16 percent of revenue is generated by suppliers that ship products exclusively within Canada;
- 81 percent of revenue is generated by suppliers that ship products to the US, Canada, or Mexico;
- Just three percent of revenue is generated by suppliers that ship products beyond North America.

This confirms the highly-integrated nature of Canada's automotive parts and components supply chain within North America. It also suggests that other international markets are not strategic export priorities for most Canadian suppliers today. As such, future EV component suppliers will benefit from building a presence in the North American market prior to shifting their focus to overseas customers. Furthermore, our analysis suggests that EV and battery supply chains in Canada will evolve in a manner similar to the existing automotive supply chain, and will follow the well-known tier structure (Figure 14).



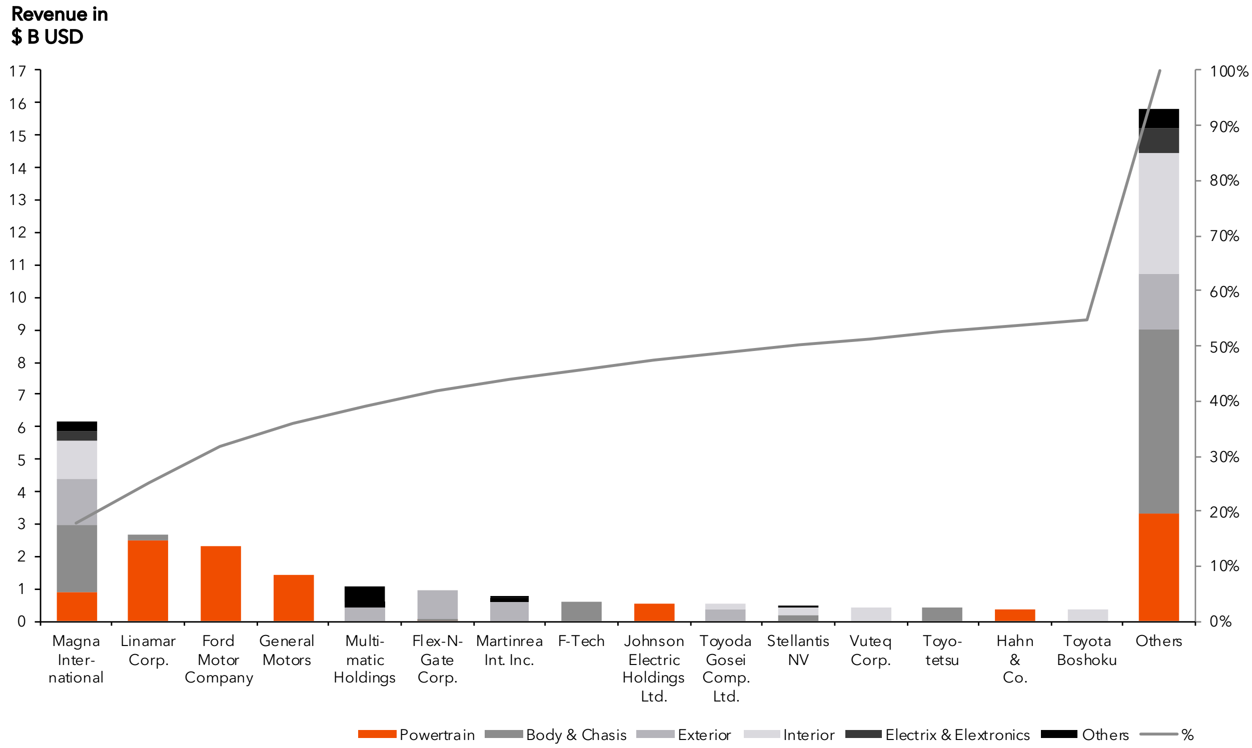
Source: Porsche Consulting
Figure 14: Supply Chain Tier Structure



Source: Porsche Consulting, Trillium
Figure 13: Final destination of Canada's automotive parts

Canada's automotive parts and components supplier landscape is dominated by large companies. The top ten largest suppliers operating in Canada generate 49 percent of total supplier revenue. The top two - Magna and Linamar - generate approximately 25 percent of total supplier revenue. (Figure 15)

Engine plants owned and operated by Ford (in Windsor) and General Motors (in St. Catharines) generate considerable revenue. These facilities combined generate approximately US$3.7B in revenue annually and employ more than 3,000 people. As a result, Ford



Source: Porsche Consulting, Trillium
Figure 15: Overview of top 15 automotive suppliers by estimated revenue generated in Canada

and General Motors, despite being automakers themselves, rank among the largest suppliers in Canada.

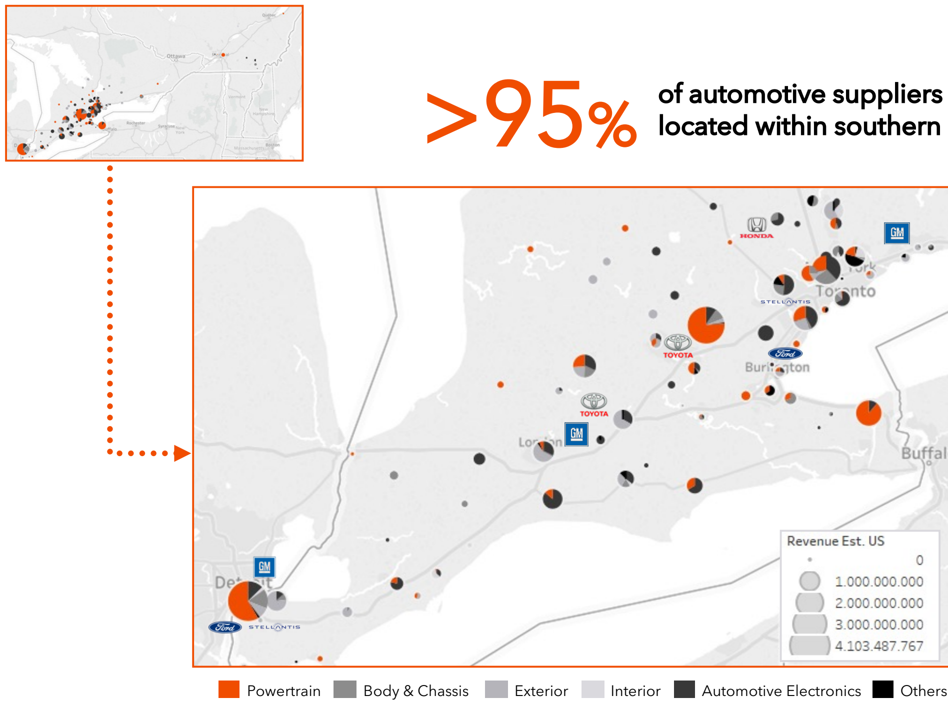
Figure 15 illustrates that Canada has long been an attractive jurisdiction for investment by globally-competitive automotive parts and components suppliers. The importance of investment by such companies should not be overlooked in future initiatives designed to support Canadian manufacturing. Policies designed to advance manufacturing in Canada must consider incentivizing investments from Canadian and internationally-owned companies alike.

Ontario's significance within Canada's automotive industry is clear. Approximately 95 percent of Canadian automotive parts and supplier manufacturing facilities are located in the southern portion of the province (Figure 16). The automotive industry plays an outsized role in Ontario's economy.

The concentration of automotive parts and components suppliers in Ontario demonstrates the influence that automakers have in attracting suppliers to the province. However, and while we do not expect to see significant increases in vehicle sales or production in North America over the next decade, we do expect that existing automakers will continue to modernize and retrofit existing assembly plants for EV production (similar to what is occurring in a number of Canadian assembly plants beginning in 2022).

New EV market entrants will require a manufacturing footprint. The existing trend of leveraging previously shuttered assembly plants for EV production by new entrants is expected to continue. This has been evident most recently with Tesla, Rivian, and Lordstown Motors. While each of these examples has created new jobs, we expect this to be offset by decreases in traditional ICE powertrain manufacturing. We do not expect these re-opened plants to attract as many supplier plants to nearby communities, as new entrants are more likely to leverage the existing supplier footprint to meet their demand. Investment attraction efforts in Canada would therefore be more effective in focusing on transforming the existing supply chain rather than attracting new automakers

As noted earlier, less than five percent of revenue generated by Canadian powertrain suppliers is related to EV parts and components. Canadian companies are, however, active throughout the broader EV supply chain. Figure 17 illustrates some of these



Note: *Size of bubble denotes amount of revenue*

Source: Porsche Consulting, Trillium
Figure 16: Canadian automotive supplier landscape

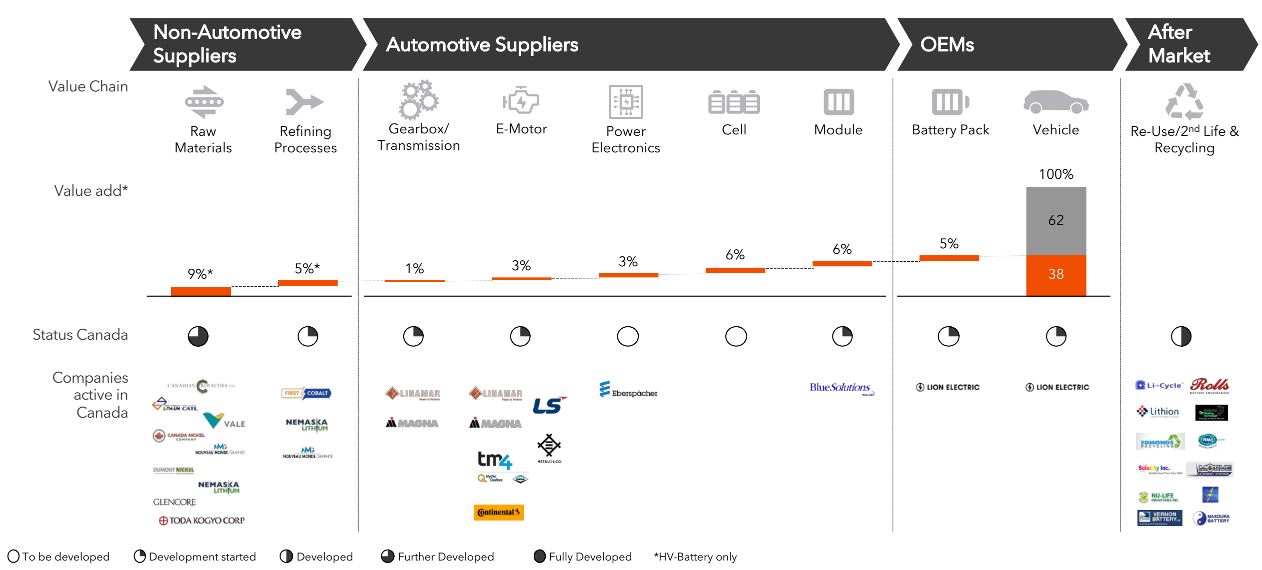
suppliers, which are active in raw materials extraction and refining and EV component production. Nonetheless, Canada's EV supply chain is fledgling and a network of suppliers is only just beginning to emerge.

Decisive action by industry stakeholders is necessary to support the transformation of Canada's powertrain suppliers specifically and the growth of a comprehensive EV supply chain generally. This is especially the case considering that battery and electrified powertrain components account for a significant portion of total vehicle costs.

The Effects of CUSMA

The Canada-United States-Mexico Agreement (CUSMA) came into force in July, 2020, replacing the North American Free Trade Agreement (NAFTA). The key provisions for the automotive industry are illustrated in the information box (right).

The CUSMA's provisions offer some benefits for the Canadian automotive supplier industry. The regional value content (RVC) requirement for core parts increased from 66 percent to 75 percent. As outlined



Source: Porsche Consulting, Trillium
Figure 17: BEV powertrain value chain overview

in the information box (right), parts are split into three categories, each with different RVC: core parts, principal parts, and complementary parts. In addition, the average hourly wage must be at least US$16 for 40 percent of the work required to produce passenger vehicles.

Lithium-ion batteries are considered core parts. This suggests that these will be made within North America in the future. Canada is potentially at an advantage for lithium-ion battery production relative to Mexico (and possibly the U.S.) due to technology, quality, and wage requirements.

The IMF projects that the CUSMA will have a slightly negative effect overall on the output of vehicle parts by each participating country (Figure 18). However, due to new wage requirements, a slight increase in exports from Canada to Mexico is expected.

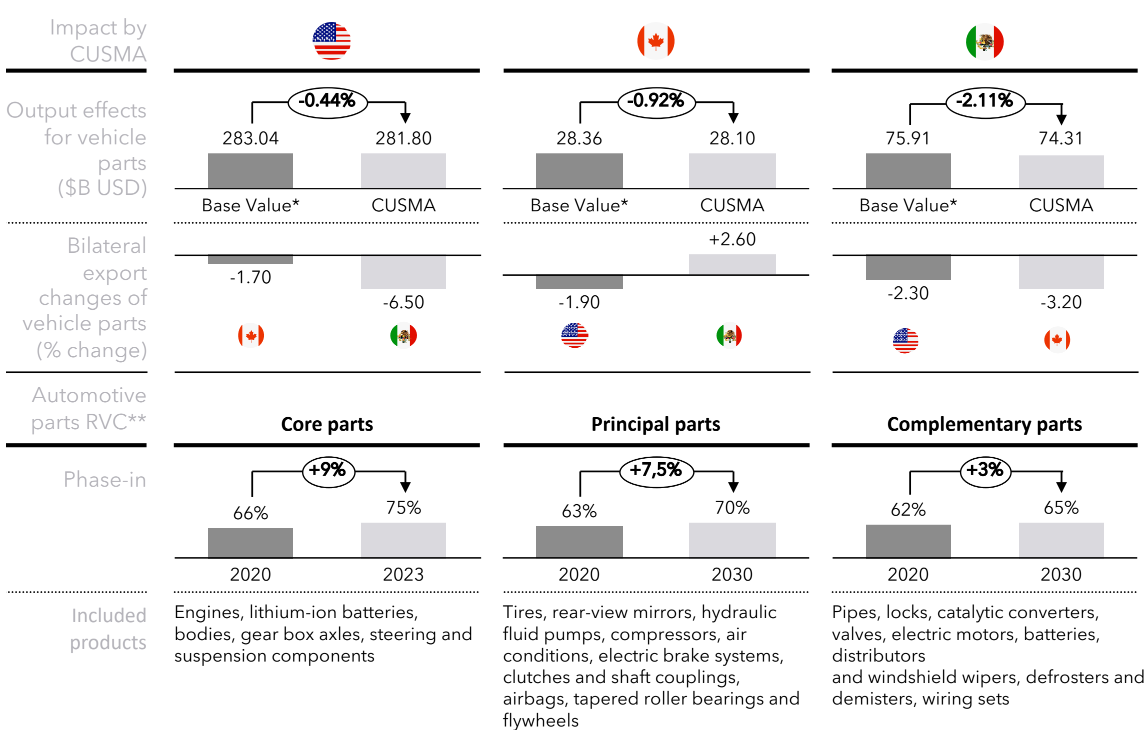
Overall, the CUSMA is not expected to significantly improve the situation of Canada's automotive supplier industry. The industry must undertake efforts to transform and should not wait for help from external forces.

Shifting Paradigms in a Fossil Fuel-Based World

EVs require many of the same parts and components used in ICEVs today. The value of ICEV powertrains is expected to increase in the short term due to the addition of HEV/PHEV components (e.g. e-motors and small battery backs), but given the relative maturity of these components and existing incumbent players, we anticipate limited opportunities for new Canadian suppliers in the ICEV, HEV, and PHEV segments.

As mentioned earlier, the transition towards EVs will reduce the volume of ICEVs produced by approximately 20 percent through 2030. Powertrain suppliers that do not expand their product portfolios can expect revenue to decrease proportionately. If the shift towards EVs occurs at a faster rate than expected, revenue will fall even more quickly.

A 20 percent market share for EVs translates to a 20 percent reduction in sales for ICE powertrain component suppliers. This reduction equates to a loss of US$2.1 billion in revenue and may place as many as 6,000 jobs at risk in Canada, with more jobs indirectly affected. With reduced volumes, automakers and suppliers will find it difficult to offset R&D costs. Plant



* Base values are from GTAP v10 database with 2014 base year, updated to reflect the effect of the CPTPP, U.S. steel and aluminum tariffs, reciprocal surtaxes by Canada, Mexico, China, and the European Union, and the U.S.-China trade tensions through August 2018 | ** Regional Value Content (requires that a product include a certain percentage of originating content)

Source: IMF, Aluminum Association

Figure 18: BEV powertrain value chain overview

utilization will also represent a challenge for powertrain suppliers, leading to overcapacity. Over the long term, overcapacity in the supply chain will reduce the price of ICE components despite higher development costs and lower economies of scale.

One important note is that powertrain component suppliers will not be the only ones affected by the shift to EVs. Automakers' engine and transmission manufacturing facilities will also be affected, potentially causing them to compensate by in-sourcing components that have traditionally been produced by independent suppliers.

Automakers' profit margins related to EVs are significantly lower than those related to ICEVs. This is due to the higher cost of powertrain components (including batteries) and increased R&D expenditures. This places cost pressures on OEMs, at least some of which will be passed along the supply chain.

While a transformation is underway for powertrain suppliers, we expect that other suppliers will be affected as well. More specifically, non-powertrain suppliers will face increased price pressure as automakers increasingly require them to offset the increased costs associated with EV powertrains.

What does this mean for Canada?

The transition to EVs threatens the powertrain supplier industry specifically, and the broader supply chain generally, unless stakeholders take measures to support the industry during this transition.

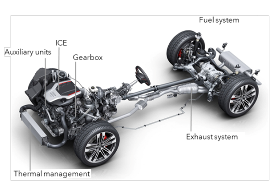
Powertrain Overview

The main categories of EVs are hybrid electric vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Battery Electric Vehicles (BEVs), and Fuel Cell Electric Vehicles (FCEVs) (see Figure 19). For the purposes of comparison, we include ICEVs.

The ICE converts chemical energy stored in a fuel, usually gasoline or diesel, into mechanical energy to power the vehicle. The ICE powertrain is complex due to the number of moving parts and components. The main components are the engine, transmission/gearbox, auxiliary units, fuel system, and exhaust system.

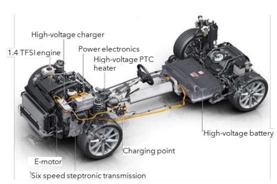
HEVs and PHEVs add an electrical powertrain to an ICE powertrain. They include an electrical motor and a small high voltage battery. HEVs and PHEVs are more efficient and emit less CO2 when compared to ICEVs. However, the HEV and PHEV powertrain

ICEV



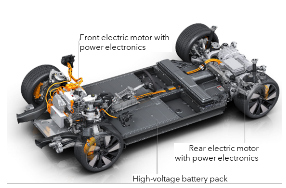
ICEV powertrains are powered by carbon-based fuels. The chemical energy is converted into mechanical energy by combustion to power the vehicle. Basic components are: ICEV, gear-box, thermal management, fuel system, exhaust system and the auxiliary components

HEV/PHEV



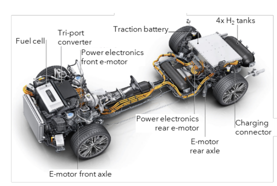
HEV/PHEV powertrains use a combination of an ICEV and an electrical powertrain. This reduces emissions and increases overall efficiency but adds complexity and new components such as the electrical motor and a small HV battery

BEV



BEVs power the vehicle using electrical motors with the energy stored in a large HV battery, eliminating the ICEV powertrain completely. Basic components are HV-battery and the e-powertrain

FCEV



Similar to BEVs, FCEVs utilize a HV battery to store energy, however it is significantly smaller, as the main energy source hydrogen is stored in a H_2-Fuel tank. The H_2 is converted into electrical energy by a fuel cell

ICEV and gearbox | E-Motor | Power electronics | HV-battery | H_2 Hydrogen fuel cell system

Source of images: AUDI AG
Figure 19: Powertrain overview

is more complex than that of an ICEV because it has both an ICE and electric powertrain.

BEVs use a large high voltage battery to store chemical energy. This chemical energy powers the electric motor(s) and does not require an ICE powertrain. BEV powertrains are significantly less complicated than ICEV, HEV, or PHEV powertrains.

FCEVs store hydrogen in a hydrogen fuel tank and convert it into electrical energy to power the vehicle in a fuel cell stack. A small high voltage battery is used to store excess energy.

FCEVs produce virtually no CO2 emissions. Overall CO2 emissions largely depend on the energy used to charge the battery of BEVs or produce hydrogen for FCEVs.

We anticipate that BEVs will remain the most dominant of the different types of low emission vehicles. HEVs and PHEVs will gradually be phased out, as they lose their relevance as a technology bridging the transition from ICEVs to BEVs.

FCEVs have a window of application in the future and will co-exist alongside BEVs just as gasoline and diesel powered ICEVs do today.

HEV and PHEV Powertrains

HEVs are propelled by a combination of a small electric motor (up to 40 kW), an ICE, and a battery with a capacity of up to 2 kWh. The electric motor supports the ICE and ensures that it operates within its ideal efficiency range. The ICE generates the electrical energy necessary to power the e-motor and charge the battery. HEVs can be driven using only electric power at slower speeds and over short distances.

HEVs include mild hybrid electric vehicles, which serve as an entry point into electrified powertrains by combining the ICE with a low-voltage (48-volt) system. This low-voltage system permits the use of electrified technologies to increase vehicle efficiency (e.g. the start-stop system or regenerative braking). However, electric-only propulsion is not possible in mild hybrid electric vehicles.

PHEVs are similar to HEVs, but they can be charged using an external power supply. PHEVs are equipped with a larger battery (< 30 kWh) and a stronger e-motor (< 120 kW) to enable electrified propulsion for longer distances (~60 km) and higher speeds (up to 130 km/h).

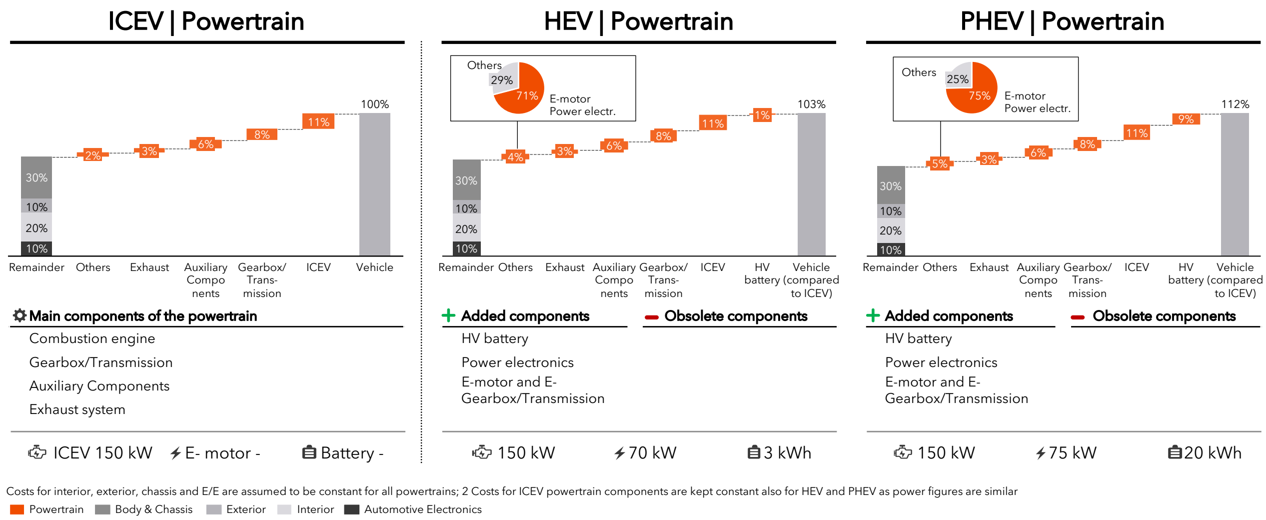
BEV Powertrains

BEVs have a fully electric powertrain. Specifications vary by model, but BEVs are, on average, equipped with an e-motor capable of at least 100 kW and a battery capacity of at least 40 kWh. The BEV powertrain consists of a high voltage battery pack and all the components necessary for an electric drive module (e.g. e-motor, e-transmission or e-transaxle, power electronics).

The battery pack consists primarily of battery modules, a battery housing, a cooling system, and a battery frame. Battery cells are stacked into modules and are usually prismatic, cylindrical, or pouch-shaped. Lithium-ion cells are the most common, with slight cell chemistry variations between manufacturers. The most common cell chemistries for EVs are nickel-manganese-cobalt and lithium-iron-phosphate.

The most notable disadvantages of BEVs include range limitations and long charging times when compared to the time it takes to refuel an ICEV, HEV, or PHEV. These two factors continue to be concerns for consumers considering purchasing a BEV. Current BEV models advertise ranges of up to 600 km (under ideal conditions). These ranges are lower than ICEVs, which often have a range of 800 km. In the future, however, BEVs will likely have a range similar to that of today's ICEVs.

Electrified Powertrain
Market Developments

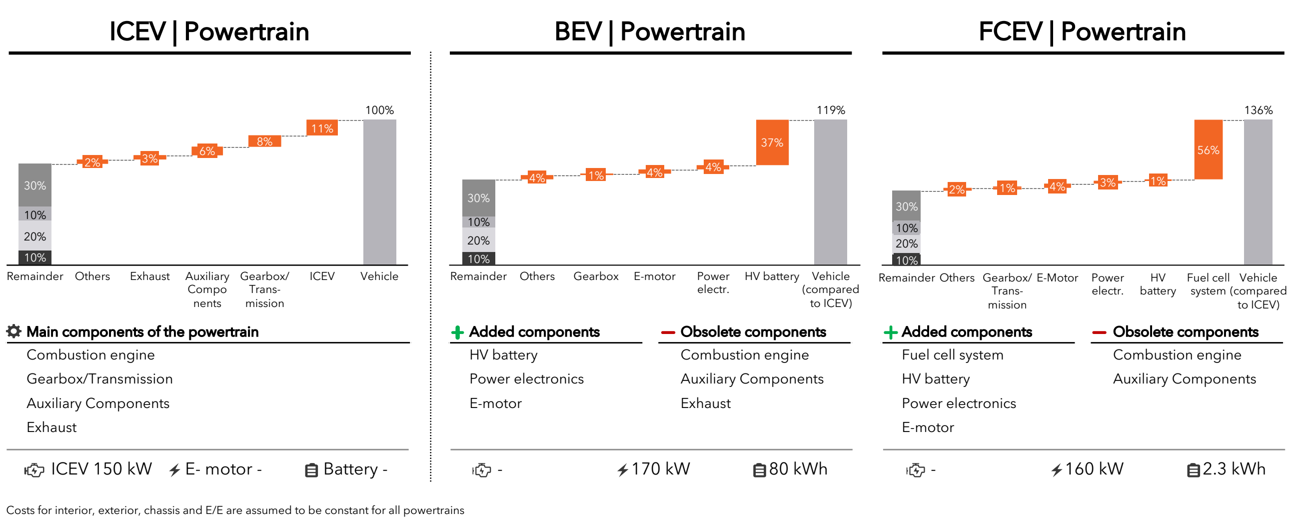


Source: Porsche Consulting
Figure 20: Powertrain component comparison (ICE vs. HEV & PHEV)

Powertrain Costs

Powertrain suppliers risk losing a substantial portion of their business if they do not transition to EV components and technologies. The powertrain, including the engine, transmission, auxiliary components, fuel system, and exhaust system, accounts for approximately 30 percent of an ICEV's value. The remaining 70 percent of an ICEV's value is made up of all other components, including the body and chassis, exterior, interior, and electronics.

HEVs and PHEVs are used as a bridging technology that helps automakers gradually electrify their vehicle offerings and meet emissions targets. HEVs and PHEVs use most of the components in an ICEV but add components for the electrified portion of the vehicle. The additional cost of the vehicle from electrifying the powertrain for HEVs and PHEVs is 3 percent and 12 percent, respectively (Figure 20). HEV powertrains are only slightly more expensive than ICEV powertrains because of the small battery size and small electric drivetrain. The larger battery is the primary reason for the increased cost of PHEVs when



Source: Porsche Consulting
Figure 21: Powertrain component comparison (ICE vs. BEV & FCEV)

compared to ICEVs and HEVs.

The addition of EV components offers additional sources of revenue for suppliers. Incumbent powertrain suppliers can leverage this opportunity to align their product portfolio to meet the changing demand and to stay relevant over the next decade.

Cost differentials between BEV and ICEV powertrains are pronounced (Figure 21). ICEV-specific powertrain components are replaced with more expensive BEV components, making BEV material costs 19 percent higher. The high voltage battery accounts for nearly 75 percent of the cost of a BEV powertrain (assuming an 80 kWh battery capacity). The remaining electrification components comprise 25 percent of the powertrain costs. BEV powertrains have 30 percent less legacy content than ICEVs but add 49 percent in content for newly electrified components (see Figure 22).

BEVs are usually more expensive than ICEVs. Nevertheless, battery prices are expected to decrease from US$115/kWh to US$50/kWh by 2030. This would narrow the cost discrepancies and drive further BEV adoption.

Battery cells account for two-thirds of total high voltage battery costs (Figure 23). In practice, battery cell manufacturers provide individual cells to Tier 1 suppliers of automakers, which then aggregate them into battery modules and battery packs. Cell manufacturing, which is currently dominated by Chinese, Korean, and Japanese companies, represents an important opportunity for Canada.

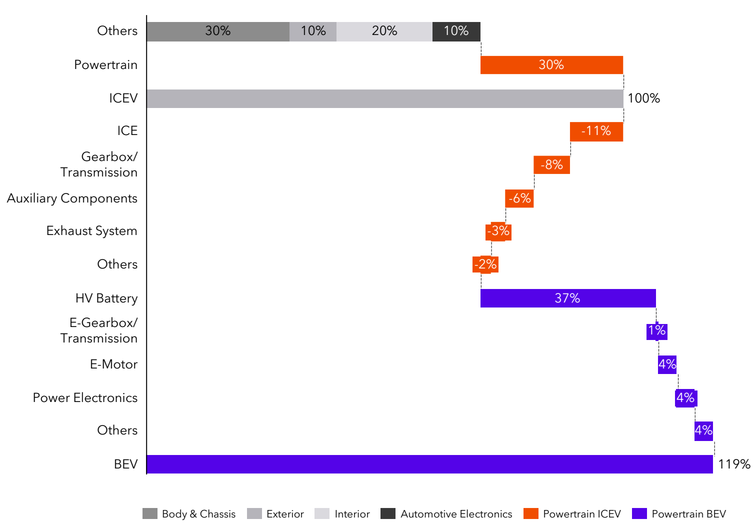
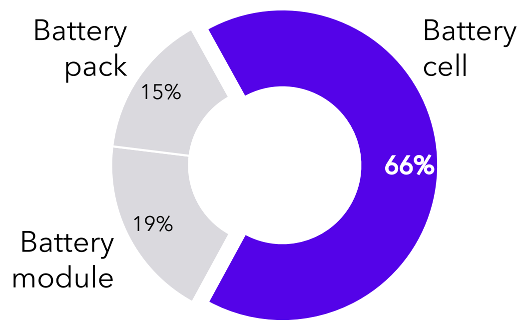


Figure 22: Component material cost share vs. the total vehicle cost (ICE vs. BEV)

FCEVs are similar to BEVs in that one component within the powertrain accounts for a large portion of the vehicle's value. The fuel system accounts for approximately 41 percent of the total cost of an FCEV, which is around 36 percent higher than an ICEV primarily because of the hydrogen storage tank. The FCEV powertrain costs 121 percent more than an ICEV powertrain.



Source: UBS

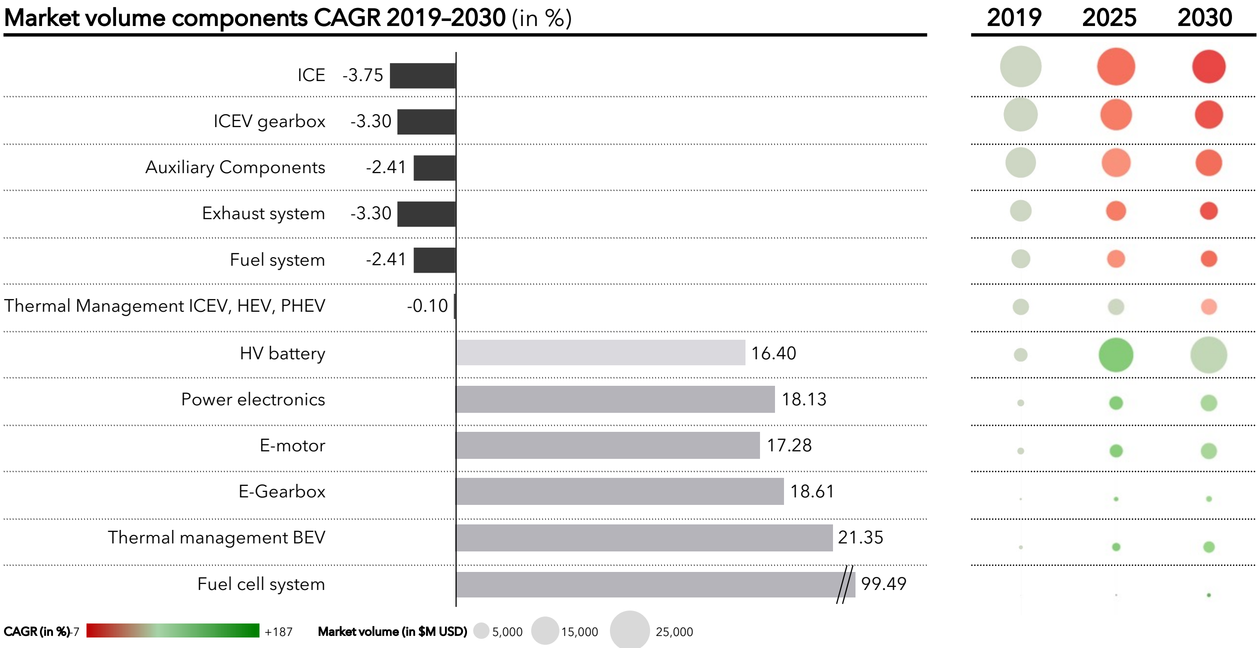
Figure 23: Share of battery costs by component

Market Outlook

We estimate the North American powertrain market for light-duty vehicles in 2019 at US$65 billion for ICEV components and US$5.5 billion for EV powertrain components. Powertrain suppliers' plants operating in Canada accounted for approximately US$11.5 billion of that market (generated almost entirely from ICEV powertrain components), as shown in Module 1.

The COVID-19 pandemic caused an approximately 20 percent decrease in the powertrain supplier market in 2020. ICEV powertrain components are not expected to return to pre-COVID levels, which means that powertrain suppliers are facing the effects of the transition to EVs earlier than originally anticipated.

We expect ICEV component revenue pools to decline at an average compound annual growth rate (CAGR) of negative 3 percent, leading to a market of US$47 billion in 2030. The rate of decline is likely to accelerate as we approach 2030. In contrast, the EV powertrain component market is expected to grow



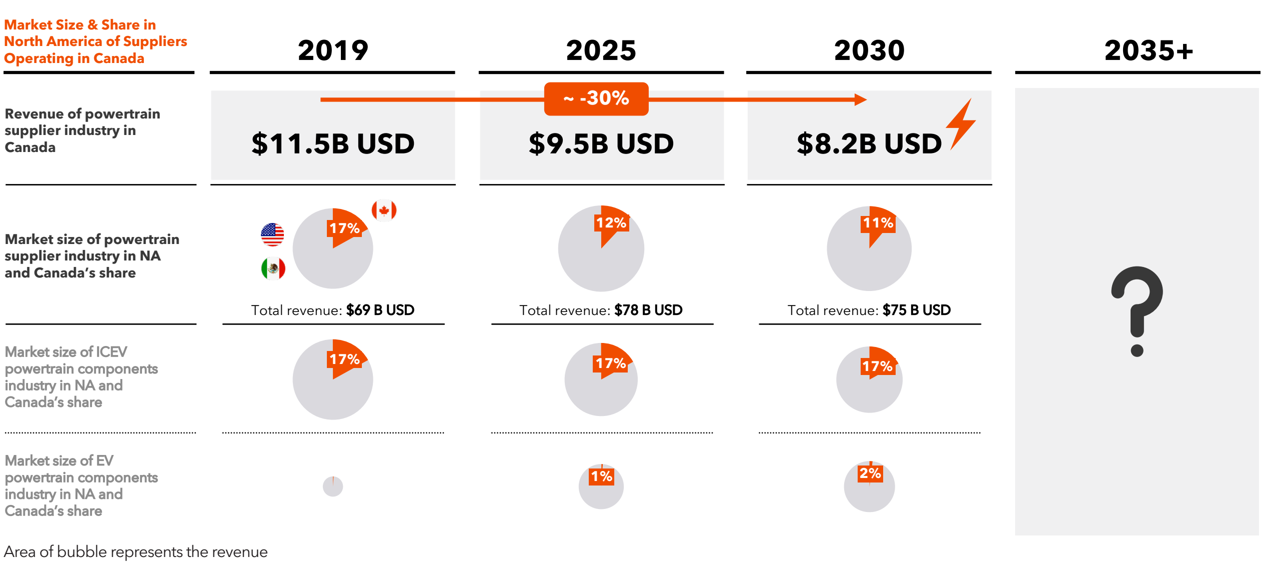
Source: Porsche Consulting
Figure 24: Market outlook for powertrain components (ICEV vs. BEV; 2019-2030)

at an average CAGR of 16 percent, leading to a projected market value of US$25 billion in 2030 (Figure 24).

The North American high voltage battery market will be the largest of all EV component markets in 2030, helping grow markets for EV components at a CAGR of 16 percent from 2019 to 2030.

When compared to all powertrain components, high voltage batteries offer Canadian suppliers the largest potential market - an estimated US$18 billion in 2030. If the market does not transform, we project a 30 percent decline in North American market share for Canadian powertrain suppliers (a US$3.3 billion decline).

In 2019, Canadian powertrain component suppliers had a market share of 17 percent. We examined powertrain cost breakdowns, vehicle production mix, and additional assumptions to estimate how much market share is at risk. Figure 25 shows that based on current trends the market share of Canadian suppliers in North America will decline from 17 percent to 11 percent by 2030. Employment in the powertrain sector would decline accordingly, with a potential loss of between 7,000 and 8,000 jobs.



Source: Porsche Consulting
Figure 25: Canadian powertrain market share in North America and expected development

BEV Powertrain

Value Chain

Figure 26: Current and future HV battery cell chemistries

	Battery technology	Application	Key materials	Cycle life* (times)	Energy density (in Wh/kg)	Power	Self-discharge	Cost ($/kWh)	Start of usage
Current technologies	**Lead acid**	Starter battery	Lead Sulfuric acid Polyvinyl chloride	200 - 300[1]	30 - 50[1]	Low	Low[1]	Low	In use
	Nickel metal hydride	Widely used in HEVs, e. g. Tyota Prius	Nickel Cobalt Composite metal	300 - 500[1]	60 - 120[1]	Low	High[1]	Medium	
	Lithium iron phosphate (LFP)	Entry level BEVs, e. g. BYD Qin	Lithium iron phosphate Carbon Polyvinylidene fluoride	5000 - 10.000[2]	150 - 180[3]	High[4]	Low[5]	Very Low	
	Nickel manganese cobalt (NMC)	Majority of BEVs, e. g. Volkswagen ID3	Nickel Manganese Cobalt	2000 - 3000[2]	180 - 300[3]	High[4]	Low[5]	Low[2]	
	Sodium-ion (SIB)	Stationary storage applications	Sodium Hard carbon Aluminum	500 - 4000[4]	120 - 180[4]	Medium	Low-Medium[4]	Low[4]	
Future technologies	**Lithium metal (solid or liquid)**	High-end BEVs	Lithium Carbon Ceramics	100 - 1000[4]	350 - 500[6]	Low[4]	Low[4]	Low-High[4]	2025
	High-manganese NMC	Volume BEVs	Nickel Manganese	2000 - 3000[2]	180 - 300[3]	High[4]	Low[5]	Low	2030
	Lithium-air	Tbd.	Lithium Carbon Metal catalysts	5 - 100[4]	500 - 700[6]	-	Eliminated[7]	-	2030
	Lithium-sulfur	Tbd.	Lithium Sulfur Carbon	50 - 100[8]	500-2500[9]	Low[4]	High[10]	-	2030

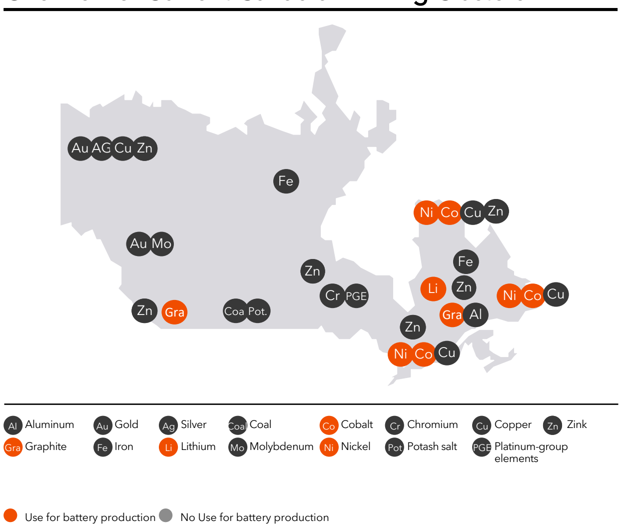
* Number of complete charge/discharge cycles that the battery is able to support before capacity falls below 80% of original capacity
Source: 1 Epec; 2 Concawe Review; 3 PowerLongBattery; 4 Nature Energy; 5 Journal of Power Sources; 6 CATL; 7 Solid State ElectroChem; 8 Electrochem;9 NPG Asia Materials; 10 Energy and Environmental Science

In analyzing the BEV component value chain, we focus on two components: the high voltage battery and the e-powertrain. Because the raw material used in the battery is key to both the performance of the battery itself and to the cost of the finished product, we look first at current and future high voltage battery cell chemistries (Figure 26).

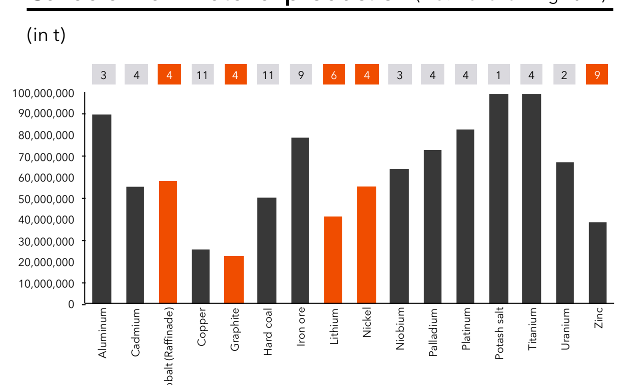
Today's mainstream lithium-ion battery cells are based primarily on lithium-iron phosphate (LFP) or nickel manganese cobalt (NMC) batteries. LFP batteries are mainly used in passenger vehicles or buses. LFP batteries are usually less expensive and have higher cycle stability, but lag behind NMC batteries in energy density. For entry-level BEVs, LFP batteries present a strong business case because of the absence of cobalt, which results in a significantly lower price than most NMC batteries being used in vehicles.

NMC batteries cost more due to the relatively high price of cobalt, nickel, and manganese. Cobalt is not required within the LFP production process, which significantly reduces production costs. NMC batteries are most commonly used in premium and luxury BEVs (like the Porsche Taycan, Audi e-tron, Ford F-150 Lightning).

Overview of Current Canadian Mining Clusters



Canadian raw material production (incl. world ranking 2017)



- Canada is a major producer in terms of potash salts, platinum metals, uranium, niobium or aluminum, sulfur, gold and diamonds. Canada also mines large quantities of nickel, cobalt and graphite, which are important raw materials for batteries.
- In 2017, the value of total commodity production was $44B USD, including $19.3B of metallic commodities and $14.7B of non-metallic commodities.

Source: DERA german raw materials agency
Figure 27: Canadian mining cluster & raw material production overview

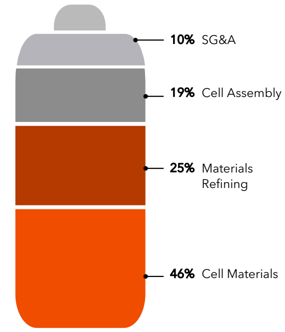
More advanced NMC cell chemistries such as NMC811 or high manganese NMC cells will further reduce the cobalt content in comparison to today's NMC622 cells. Figure 26 illustrates current and future cell technologies and chemistries.

The strong market growth of BEVs significantly increases raw material demand for lithium, nickel, cobalt, and graphite. Lithium-ion batteries for automotive applications are expected to see an annual growth of more than 28 percent through 2030, which will account for more than three-fourths of total lithium demand. This will have a direct impact on the types of lithium compounds required by the industry. Nickel demand is also expected to climb, with a projected 32 percent CAGR between 2019 and 2030. Demand for cobalt will double by 2030 but is expected to slow as cell manufacturers look for ways to reduce the cobalt content of batteries.

Most reserves for these materials are located in a few countries: the U.S., Russia, China, and Canada. Figure 27 illustrates mining production in Canada.

Canada, which currently ranks fourth in the world in cobalt production, third in nickel production, and third in graphite production, has large reserves of these resources and can mine them competitively. Canada also ranks sixth in the world in terms of lithium production, but has only recently begun exporting lithium in significant quantities.

With North American demand for high voltage batteries growing from 32 GWh in 2020 to 277 GWh in 2030, the mining, refining, and processing of battery



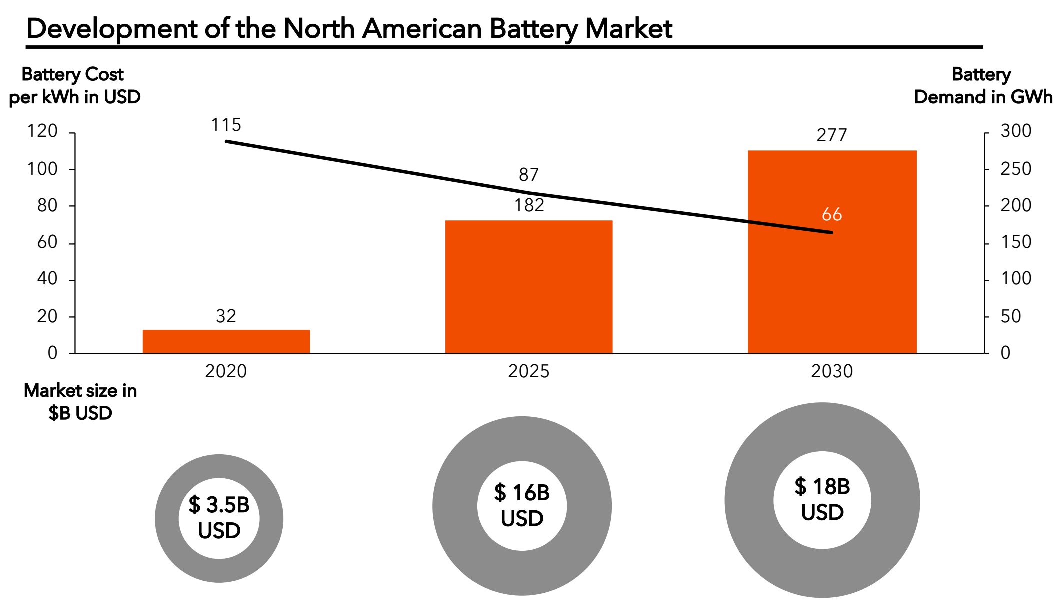
Source: UBS
Figure 29: HV Battery Cell Cost Breakdown

materials presents a significant opportunity for Canada. However, there is a risk that the value of battery materials will decrease as automakers and battery manufacturers seek out more cost-efficient materials and chemistries.

As battery cells use increasingly smaller amounts of the most valuable materials, the price of batteries will fall. This in turn limits the future growth of the market as well as the potential of supplying materials for battery cell production.

Figure 28 illustrates the development of the North American battery market.

Despite the abundance of raw material reserves, Canada must expand beyond extraction to ensure that



Source: IHS Markit, Porsche Consulting
Figure 28: Future HV battery cost, demand and market size

this country secures a meaningful part of the battery supply chain. Focusing solely on mining excludes 55 percent of the battery cell's value and 65 percent of the value of the battery pack (equal to US$18B in 2030) as shown in Figure 29.

Focusing on both raw material extraction and refining, on the other hand, would provide an addressable value of US$13B in 2030 for battery packs produced in North America. Because mining and refining capacities for battery-grade materials are not fully developed in Canada, we believe that stakeholders should focus on two main activities to maximize these opportunities:

- Increase capacity to mine and refine battery-grade materials;
- Integrate mines and refineries with future battery cell and module factories.

Given the geographical distribution of mines and mineral deposits across Canada, a cross-provincial initiative is necessary to connect mines and refineries in northern and western regions with manufacturing facilities in Ontario and Québec. Canada will otherwise remain a supplier of raw materials to battery manufacturers (primarily in the U.S.) and will lose out on annual revenues of up to US$10B related to battery manufacturing.

HV Battery Manufacturing

Canada has a prime opportunity in manufacturing high voltage battery cells, modules, and packs. As the key customers of BEV components, automakers create a strong pull in the supply chain, fostering the growth of a healthy supplier landscape. Production of several BEV models has been announced in Canada. However, they are projected to account for only four percent of total light-duty vehicle production in Canada by 2025. As a result, demand in Canada for high voltage batteries will remain low, reducing the attractiveness of Canada as a site for battery cell manufacturing.

Approximately 50 GWh of the 495 GWh of the battery cell production capacity announced for North America is expected to be located in Canada. This includes LION Electric and the joint Stellantis and LG battery plant in Windsor. BritishVolt and Canadian-based StromVolt also hope to build battery manufacturing capacity that could see an additional 70GWh of battery cell production added to these totals.

Other cell manufacturers have either already begun operations or have announced plans to establish a footprint in the U.S. in the next five years.

Canada must leverage its strengths if it wants to grow

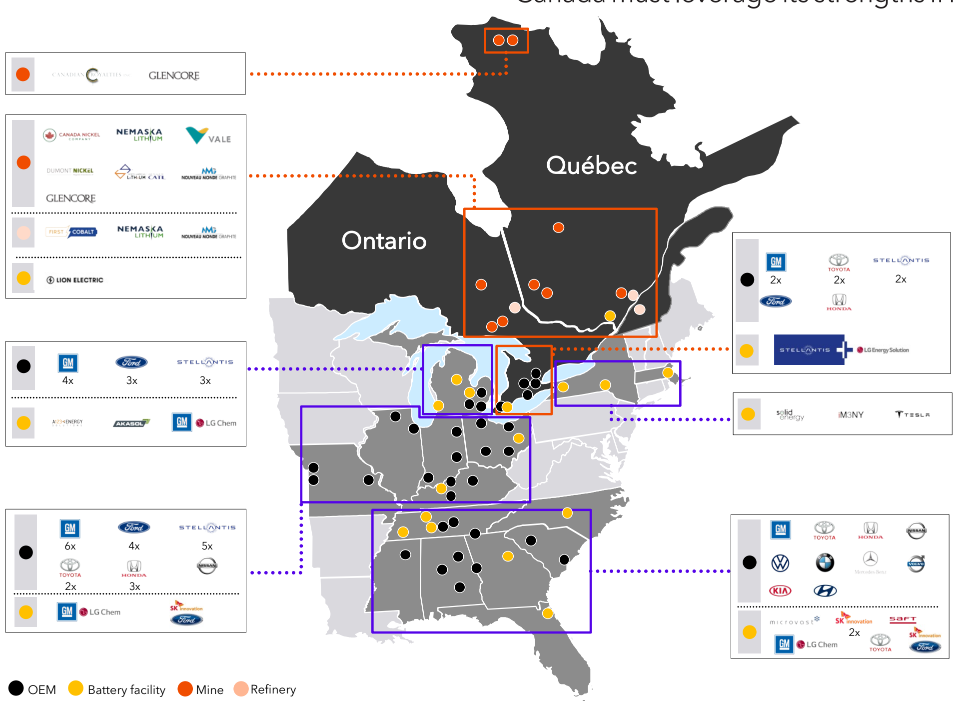


Figure 30: Overview of Select EV supply chain facilities in North America

domestic battery production. Mining is one critical segment of the battery supply chain that Canada has the competence and resources to support.

Figure 30 shows that Canada is strategically located to supply North America with battery materials and components due to the abundance of battery-critical minerals and metals (e.g. lithium, nickel, and cobalt). To do so successfully, however, involves building a supply chain that supports mining, refining, and processing these minerals into battery-grade materials. It also means expediting investments in factories that produce battery components, cells and modules.

In addition to battery cells and modules, the battery pack offers opportunities for suppliers. The battery pack consists of cell modules, battery control units, cooling systems, battery frames, and harnesses. Traditional suppliers can provide fully assembled battery systems or sub-systems to automakers. The sub-components do not require complex manufacturing processes, and existing suppliers should be able to adapt. Because of this, battery pack manufacturing offers a potentially lucrative opportunity for Canadian suppliers.

Substantial reductions in the cost of batteries are expected by 2025. These can be grouped into three categories:

- Cell optimization (e.g. a reduction of cobalt content and standardized cells)
- Production process optimization (e.g. faster process and improved first-pass quality rates)
- Location and factory scale (e.g. labour costs and economies of scale related to production volumes)

Battery manufacturing represents a prime opportunity to leverage advanced manufacturing concepts and digital transformation in Canada. Relevant cases for battery cell production include:

- Advanced machinery and process automation through artificial intelligence (AI)
- Data-driven process optimization

Process stability is key to preserving product quality. End-to-end data processing and advanced analytics offer significant cost reduction potential. Equipment and process automation infrastructure offers a potential revenue pool for Canadian machinery suppliers to extend their existing capabilities and apply advanced manufacturing concepts.

Once machines have been equipped with the proper sensors and process parameters (e.g. line speed, temperature, moisture, defect rates, and coating thickness), there are abundant opportunities within big data applications. Based on these potential applications, we anticipate significant opportunities to increase productivity and reduce costs. The data accumulated from end-to-end process digitization can be used for more than just incremental improvements of traditional performance indicators; they can also be leveraged for advanced analytics and predictive maintenance or data-driven process optimization.

Advanced manufacturing use cases and principles will allow battery and EV component manufacturing facilities to lead the adoption of advanced manufacturing processes in Canada.

Second-Life Applications and Battery Recycling

With the introduction of mass-produced high voltage batteries, many have considered the possibility and benefits of second-life applications or specific recycling strategies once the battery has degraded below a certain state of health or performance threshold. While there is a need for both, this market will remain relatively small through 2030, largely due to technology as well as supply and demand constraints.

NMC batteries are not as suitable for second-life applications as LFP batteries. In the future, we expect responsibly manufacturing LFP batteries to be less expensive than extracting a used NMC battery from an EV.

Furthermore, the supply of used batteries will continue to grow, with significant volumes of used batteries expected in the early 2030s. The market for second-life applications will only account for a fraction of this, which will make recycling the most plausible option for end-of-life batteries, with the largest volume of batteries beginning to resurface in 2035.

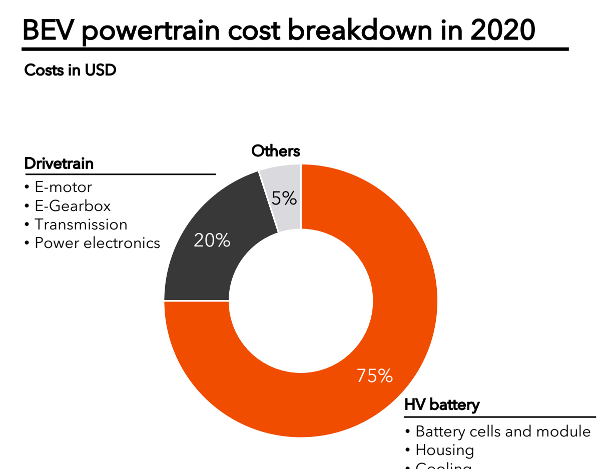
Recycling can be profitable, but it will likely be viewed by automakers as an obligation rather than a core revenue stream, especially as new battery cell developments reduce the volume of cobalt required. Reaching sufficient profitability margins will be an obstacle, particularly in less densely populated areas where the costs of transporting end-of-life batteries to a centrally located recycling facility are high.

E-Powertrain

While e-powertrains comprise just 20 percent of the value of a BEV powertrain (Figure 31), this segment represents a strong opportunity for existing suppliers. This is primarily due to the relatively low transition costs as the processes and parts involved are similar to those used in ICEV powertrains.

The rest of the e-powertrain also offers potential, with 13 percent of total material costs consisting of the e-motor, e-transmission, power electronics, and other components.

E-motors are simpler than ICEs - they consist of 17 to

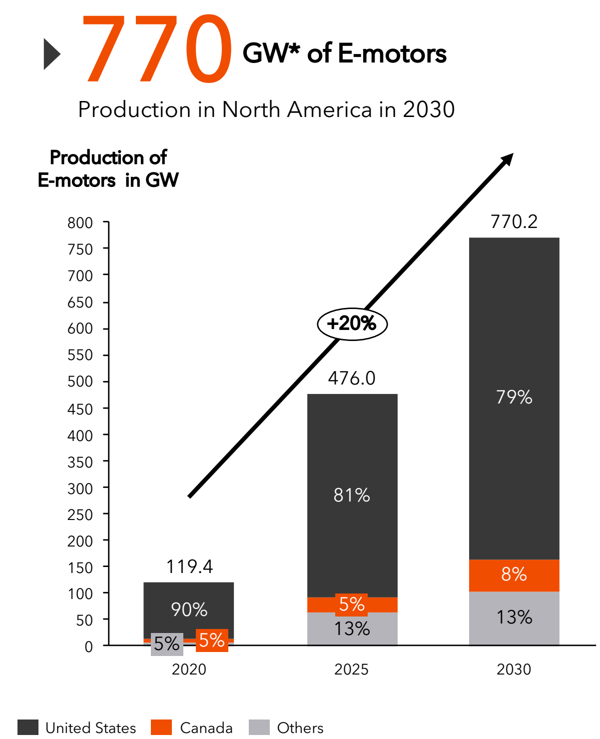


Source: Porsche Consulting
Figure 31: BEV powertrain cost breakdown (2020)

25 parts, as opposed to the 1,200 parts needed for an ICE. E-motors also require fewer labour hours in production and final assembly. As demand decreases between 2030 and 2035, this will be significant for ICE component suppliers. Comprehensive workforce plans to support the transition from ICE to e-motor will prove important, keeping in mind that ICEV production will continue into the 2030s.

The e-motor market is expected to grow, with a projected CAGR of 32 percent between 2020 and 2025 and 10 percent between 2025 and 2030. E-transmission and power electronics markets are expected to have similar growth rates, as can be seen in Figure 32.

Most e-powertrain component manufacturing requires traditional process competencies, which creates a



Source: IHS Markit, Statista, Porsche Consulting
Figure 32: E-Motor production in North America (2020-2030)

sufficient opportunity in the existing Canadian supply chain. Canada's suppliers have realized competences in the casting, forging, and machining processes necessary to manufacture these components. The only gap in today's supply chain is related to power electronics, where Canadian suppliers have a limited footprint.

As with high voltage batteries, some automakers - including Tesla and Volkswagen - have in-sourced e-motor production, while other automakers rely on Tier 1 suppliers, such as the LG Magna e-Powertrain joint venture. Tesla and LG Magna e-powertrains are expected to lead e-motor production in North America by 2025.

In addition to LG and Magna, Marelli has announced a joint venture with PUNCH to supply e-axles. Marelli will provide e-motors, inverters, and software, while PUNCH will provide transmission components.

Production of e-powertrain components is a key opportunity for Canada's supplier industry. Upgrading the traditional powertrain supplier base will allow companies to deploy advanced manufacturing principles to create lighthouse projects across the country.

The capital intensive industry that produces e-powertrain components offers multiple possibilities for advanced manufacturing use cases. We discuss two below:

- Predictive maintenance
- Human-machine cooperation and automated guided vehicles (AGVs)

Predictive and smart maintenance offers a significant opportunity for EV component plants. Big data-based algorithms can predict machine failures in advance and notify maintenance crews immediately. Digital tools such as wearables and augmented reality can assist in failure analysis and repair, reducing downtime.

Improved human-machine cooperation and AGVs offer the potential to reduce costs and bring the future of advanced manufacturing to life in Canada. Further use cases can be found in the application of artificial intelligence (AI). Examples include image or voice recognition and digital shop floor boards that use real-time data from the production line.

Opportunities are abundant, and now is the time to turn the challenge of transforming the powertrain supplier base into an opportunity.

Easily and openly accessible public funding, including loans and non-repayable grants, for advanced manufacturing pilot projects will be needed - particularly to support small and medium-sized enterprises with limited access to capital and human resources. Successful pilot projects will also require a broad application of advanced manufacturing principles - broad enough to reach the factory floor.

Research & Development

Canada has a large, internationally-recognized ecosystem of research institutions and publicly-funded universities and colleges. This ecosystem offers an advantage Canada can leverage to develop leading technologies related to EVs. The NRC for example has significant industrial R&D activities in battery technologies, electric motor development and hydrogen applications within the Clean & Energy Efficient Transportation program. Tesla, for example, tapped into Canadian researchers' battery expertise at Dalhousie University in Halifax to help it introduce a lower-cost battery with a longer life designed to reduce the cost of BEVs. Tesla also recently established its own battery research laboratory in Halifax and acquired a Toronto-area manufacturer of automated battery assembly technologies (Hibar Systems) in 2019, and has subsequently expanded its Toronto-area operations.

Additional opportunities for public/private partnerships include leveraging institutions such as Transport Canada's Innovation Centre, the University of Toronto Electric Vehicle Research Centre (UTEV) and the Québec-based Innovative Vehicle Institute (IVI), as well as Canadian-headquartered companies such as Ballard and New Flyer Industries.

Canada has historically supported the automotive industry through government programs that offer incentives for R&D. Current programs include the National Research Council's Industrial Research Assistance Program (IRAP) and federal tax credits offered by the Scientific Research and Experimental Development (SRED) Program. While helpful, these programs have not been enough to allow Canadian suppliers to develop a strong position within global EV R&D networks. They do not, for instance, support the pilot use-case applications and production scale-up and testing necessary to commercialize research and new technologies in Canadian manufacturing. Three of the four largest Canadian suppliers (Magna, Linamar, and Martinrea) conduct the majority of their R&D outside of Canada (Multimatic performs the majority of its R&D in the Toronto area). Canada stands to benefit from a renewed focus on developing programs to support applied EV R&D in the country. Otherwise, suppliers and automakers will continue to locate their R&D activities elsewhere, where product development for manufacturing is less expensive and easier because of greater economies of scale.

Opportunities within the HEV and BEV Powertrain Value Chain

Canada has the necessary ingredients to create an integrated EV supply chain. Initiatives designed to achieve that goal, including the recently-announced Accelerate network, which includes Electric Mobility Canada (EMC), are underway across the country.

This section highlights seven opportunities to develop an integrated EV value chain in Canada. Rather than making formal recommendations, it identifies potential opportunities to explore.

1. Leverage Canada's abundant raw materials and refining processes to create a seamless BEV value chain.

Canada has substantial mineral deposits that can be further processed to produce battery cells. With an established mining industry that accounts for five percent of Canadian GDP, Canada offers large reserves of these critical minerals as a competitive supplier.

The automotive industry will need an additional 30,000 tonnes of cobalt and 81,000 tonnes of lithium each year to produce high voltage batteries. The battery cell itself comprises approximately 20 percent of the cost of a BEV, and 71 percent of the cost of the battery cell is related to minerals and metals, making them key components of this value chain (see Figure 29).

Canada has some of the world's richest lithium, nickel, cobalt, graphite, manganese, and copper deposits. With numerous exploration and mining development projects underway across the country, Canada is well-positioned to meet the growing global demand for battery metals. In theory, this makes Canada a prime location for battery cell manufacturers, although Canada currently lacks strong commitments from these companies.

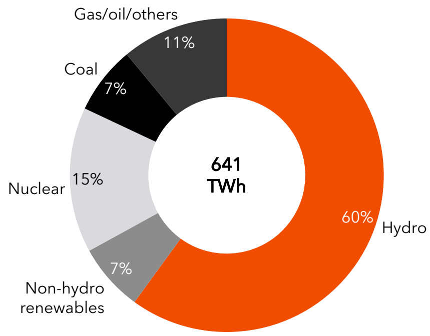
Nevertheless, reports such as 'What We've Heard' from the Canadian Metals and Minerals Plan (CMMP) have identified significant barriers that should be addressed. These barriers include a lack of access to mineral deposits due to insufficient infrastructure and lengthy regulation processes. Minimizing these barriers will be important if Canada is to develop its full potential as a supplier of battery materials.

By locating in Canada, battery cell manufacturers can establish a footprint proximate to mines and refineries. This helps mitigate potential supply chain disruptions and reduce their carbon footprint. Battery cell manufacturers could also potentially enter into supply agreements with mining and refining companies in order to help integrate chemical processing and cathode/anode manufacturing into the supply chain. This may also help reduce the cost of manufacturing batteries and, by extension, the cost of BEVs.

Canada can also take advantage of the growing demand for socially and sustainably mined resources. Automakers such as Ford, General Motors, and Volkswagen have placed increasing emphasis on ensuring that their supply chains meet criteria set forward by the OECD. Volkswagen, for its part, has started evaluating all of its suppliers using environmental, social, and anti-corruption criteria.

Canada also has a competitive advantage related to the sources it relies on for electricity generation. Currently, over 80 percent of the electricity generated in the country comes from sources that do not emit greenhouse gases (Figure 33). In Ontario, Québec, and Manitoba, where the majority of Canada's automotive industry supply chain is located, the proportion of electricity generated from sources that do not emit greenhouse gases exceeds 95 percent.As automakers strive to reduce their carbon footprint, sustainability becomes a decisive factor when choosing how to source components manufactured using energy-intensive processes (i.e. batteries). For example, Volkswagen has identified that 'green' sources of

Energy generated in Canada by source in 2018



Source: https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/electricity-facts/20068
Figure 33: Canada's energy generation by source

electricity are one of the key levers available to decarbonize the supply chain. To that end, the company has created a global requirement to ensure that batteries are sourced only from suppliers that use green energy exclusively. This trend is likely to spread to other automakers that are looking to reduce their carbon footprint.

Canada will benefit from focusing on efforts to provide the battery supply chain with sustainably and responsibly mined resources. Some efforts are already underway, including Investissement Québec's Project Bellevue, which aims to develop a clean and traceable battery cell supply chain.

2. Leverage joint ventures and partnerships to overcome barriers to entry and harmonize battery pack manufacturing processes.

Canada can encourage the production of the necessary battery chemicals, anodes, cathodes, cells, modules, and packs used in BEVs. While suppliers may compete with automakers for these activities, joint ventures and partnerships can create a more cooperative and collaborative ecosystem. For example, automakers such as Tesla, General Motors, and Volkswagen hope to develop relationships within mining companies in order to secure access to raw materials. Securing this access helps create a seamless supply chain that includes automakers, the companies developing innovative battery chemistries, and those mining and refining raw materials. This can provide a competitive advantage to suppliers seeking to stay on the leading edge of battery cell technology and maintain a competitive market position.

While many automakers with an existing footprint in Canada have established joint ventures or partnerships with battery cell manufacturers (e.g. Ford and SK Innovation's BlueOval SK), these partnerships have largely been created in the U.S. As BEV production increases, these partnerships will play an important role in supplying automakers. They also provide an entry point for battery cell manufacturing in Canada in the medium term.

3. Leverage Canada's HV battery and R&D network to expand current technologies and attract additional investments

Canada's willingness to fund automotive technologies, when combined with its world-renowned research institutions and highly-talented personnel, offers an advantage to manufacturers seeking to develop new battery technologies (e.g. solid-state), decrease production costs, and realize efficiencies associated with cutting edge advanced manufacturing processes and technologies.

The auto industry faces a severe labour shortage, especially in those high-tech skills necessary to design, engineer, develop, and manufacture components and parts for EVs. Canada's expertise in AI can help to tackle this problem. AI-enabled rapid prototyping and testing capabilities that are already resident in Canada can be leveraged to support Canadian manufacturers and attract more investment, R&D activity, and potentially product development and manufacturing to Canada.

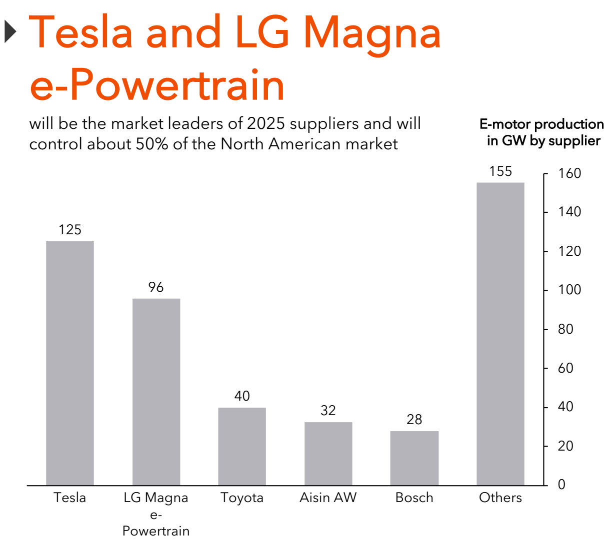
For example, the automotive industry could build on Canada's leading artificial intelligence (AI) expertise and capabilities. Canada has an existing suite of AI-enabled rapid prototyping and testing capabilities (e.g., McMaster Automotive Research Centre (MARC); the Materials Acceleration Platforms at National Research Council of Canada (NRC), CanMet, University of British Columbia, and the University of Toronto) that can be leveraged to support Canadian manufacturers and to attract more investment and R&D activity to Canada.

4. Leverage Canada's position in recycling to create a profitable business stream

Battery recycling is profitable. A significant volume of first-life batteries will be directed towards recyclers beginning in 2035. Despite an expected reduction in profitability related to lower value mineral content, we believe that regulators will require that end-of-life batteries exist in a closed loop system, providing an opportunity for recyclers in North America. Propulsion Québec, for example, recommends that governments implement an extended producer responsibility mechanism for EV batteries. This would certainly spur growth in the North American recycling market. Several Canadian companies have expertise in battery recycling, which positions them well to extend their market position.

5. Smaller suppliers can transition to new products that leverage internal expertise and build joint ventures to access new competencies

BEV powertrain sub-component manufacturing offers an opportunity for suppliers with expertise manufacturing ICEV powertrain components to transition to producing EV powertrain components. These suppliers and associated stakeholders would benefit from developing an action plan to ensure that they will play a role in the automotive industry's electrified future.



Source: IHS Markit, Statista, Porsche Consulting
Figure 34: E-motor production in North America by supplier

6. Leverage large Tier 1 suppliers for e-motor and e-transmission production

A significant number of automakers, including Tesla, Toyota, and Volkswagen, expect to assemble their e-powertrain in-house. There are, however, ample opportunities for Tier 1 suppliers to contribute to e-motor and e-transmission production. One approach for traditional powertrain suppliers involves leveraging joint ventures to begin producing e-motors. Figure 34 illustrates one such opportunity: the LG Magna e-Powertrain joint venture. This joint venture is expected to become the second largest e-motor producer in North America by 2025. Tier 2 and Tier 3 suppliers, for their part, can provide other components, such as rotors, stators, or basic industrial products like high-grade copper wire and sheet metal to automakers and Tier 1 suppliers. Even if a majority of automakers assembly e-motors and e-transmissions in-house, a number of smaller components will be required of Tier 2 and Tier 3 suppliers.

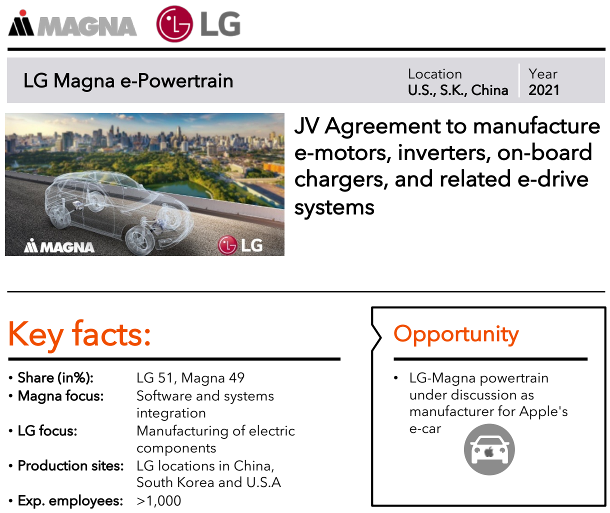
Case Study: LG Magna e-Powertrain

The partnership between Magna and LG Chem provides a useful example of a joint venture that allows two companies to leverage their respective expertise in order to develop a prominent position in the e-powertrain market. Figure 35 identifies the core tenets of the partnership, which will produce e-motors, inverters, on-board chargers, and related e-drive systems. The partnership leverages Magna's expertise in powertrain manufacturing and LG's expertise in battery manufacturing and development.

7. Establish an ecosystem to produce power electronics

Canada's existing automotive electronics manufacturing industry is small. There is a substantial opportunity, however, to grow that industry. This could be done by focusing on developing competencies related to EV power electronics - a market that is expected to grow to US$3.7B by 2030.

There are also opportunities for suppliers to produce integrated systems that include inverters, DC/DC chargers, and onboard chargers that can be modularized and produced at scale for multiple customers.



Source: IHS Markit, Statista, Porsche Consulting
Figure 35: LG Magna e-Powertrain case study overview

FCEV Powertrain Value Chain

Status Quo and Outlook

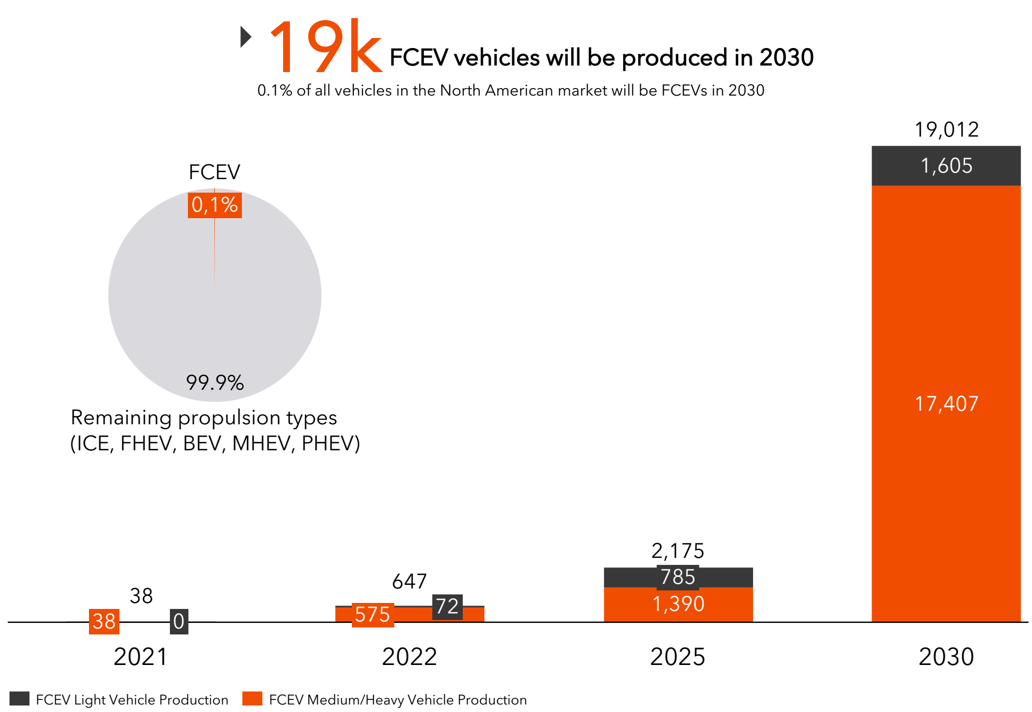
While originally considered a combustible fuel when ICEVs were first developed, hydrogen never emerged as a serious alternative to gasoline or diesel due to safety concerns. Today, however, several automakers, research institutions, and government agencies see opportunities to leverage the benefits of hydrogen in fuel cell applications. Despite the dominant future of BEVs, a window of opportunity may exist for FCEVs.

The current forecast for North American FCEV production in 2021 includes just 38 medium- and heavy-duty commercial vehicles and no light-duty vehicles. Annual production volume is, however, expected to increase to 19,000 by 2030 (Figure 36).

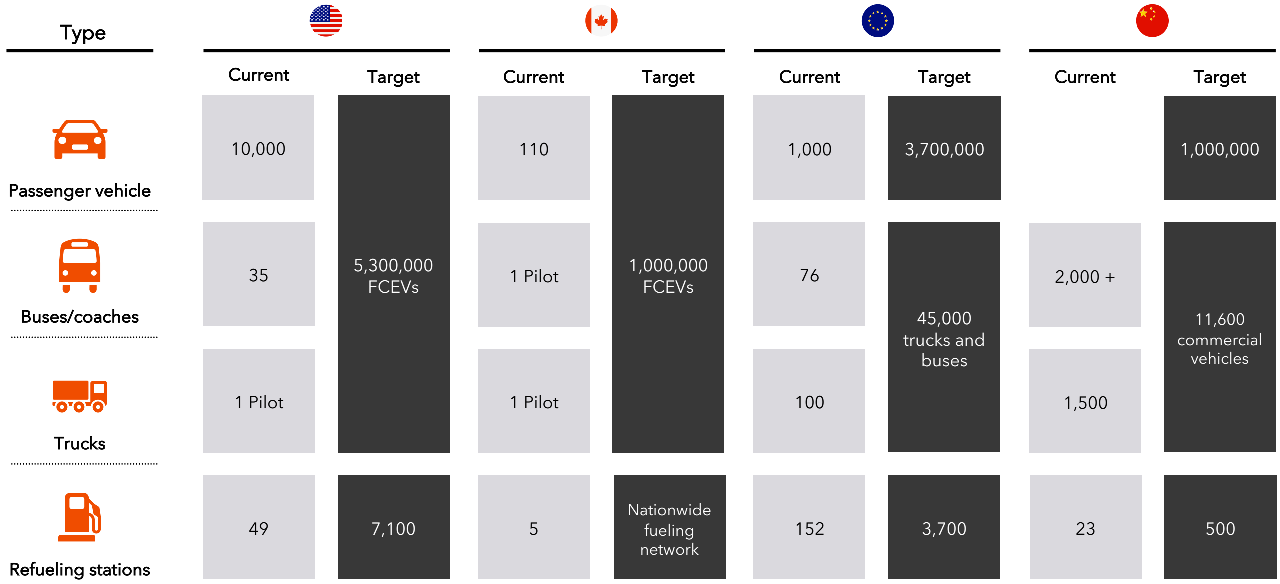
Over the same period, the overall annual light-duty vehicle market is projected to remain at 16.7 million while the annual medium- and heavy-duty commercial vehicle market is expected to increase to 632,000.

FCEV Targets by Region

There are about 110 light-duty FECVs operating in Canada and 10,000 in the U.S. (primarily in California). Despite these low rates of adoption, Canada is targeting more than one million FCEVs by 2030 and five million by 2050. The U.S., EU, and China have similarly aggressive FCEV targets (see Figure 37). Japan, for its part, aims to have 200,000 FCEVs on the road by 2025.



Source: IHS Markit
Figure 36: LG Magna e-Powertrain case study overview



Source: Roadmap to a U.S. hydrogen economy, nrcan
Figure 37: Current and target number of FCEVs by type and region by 2030

These targets are optimistic given the slow adoption of FCEVs, lack of significant technological advancement in fuel cell technology, and lack of commitment to FCEVs by automakers.

While each country has implemented policies to promote the commercial introduction and adoption of FCEVs, results have been lacklustre. Meeting established targets will require each country to reallocate resources and make significant investments in infrastructure and consumer incentives.

Fuel Cell Landscape

Canada has more than 25 suppliers and R&D centres dedicated to fuel cell technologies. Most are located in British Columbia. The Canadian Hydrogen Fuel Cell Association (CHFCA), which includes industry, academia, research agencies, and other stakeholders, exists to advance the use of clean hydrogen and fuel cell technologies.

With innovative companies such as Ballard, New Flyer, Hydrogenics, and Loop, Canada's network of fuel cell expertise has earned the country a spot among global leaders in FCEV R&D.

Canadian FCEV technology powers more than half of the 2,000 fuel cell electric buses in service worldwide. These technologies have also been used in the first hydrogen-powered commuter train. Canada is positioned to be a global leader in the fuel cell industry and has significant opportunities for growth on a global scale.

There are, however, few domestic or North American initiatives associated with fuel cells. Without the ability to deploy technologies within North America, Canada will be forced to rely on overseas markets for its fuel cell technologies, placing it at a competitive disadvantage vis-a-vis local and regional suppliers.

Despite aggressive targets and R&D capabilities, the FCEV market will remain small. Efforts by Canada to advance FCEV technology will fail to compensate for losses in ICEV technology and manufacturing.

FCEVs vs BEVs

BEVs will outperform FCEVs in the light-duty vehicle sector for the foreseeable future This section explains why.

Efficiency

Both BEV and FCEV powertrains use electricity. Batteries store and deliver energy to the BEV powertrain, whereas FCEV powertrains generate electricity by converting hydrogen (via reverse electrolysis) while also delivering energy. FCEVs primarily use batteries to regulate fluctuations, absorb additional power, and release power as required. As a result, FCEV batteries typically have a lower capacity than BEVs (1-3 kWh vs. 40-200 kWh).

Figure 38 compares the well-to-wheel efficiency of BEVs and FCEVs. BEVs have an overall efficiency of 75-80 percent, whereas FCEVs have an efficiency of 30-35 percent. This means that about one-third of the electricity generated by FCEVs is eventually used to propel the vehicle. This is due to the large amount of energy required to produce hydrogen through electrolysis and the inherent inefficiencies in converting hydrogen to energy.

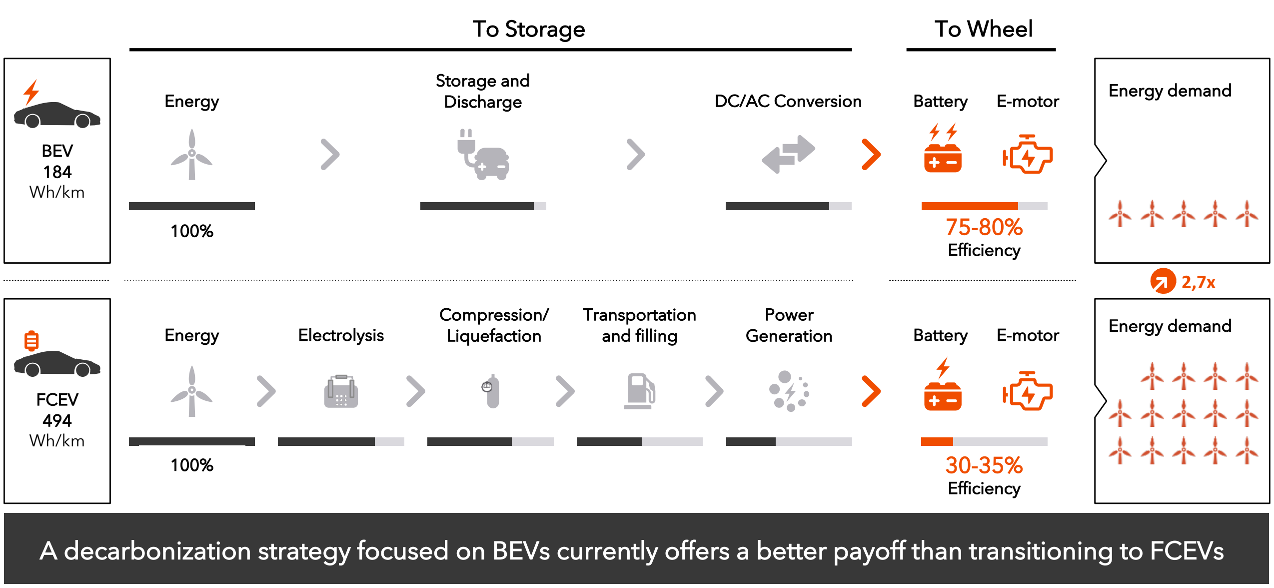
Because conversion is inefficient, it is usually less expensive to recharge a BEV than to refuel a FCEV. Of course, the taxation of hydrogen and electricity play an important role in the eventual costs, and must be considered in any cost-based analysis moving forward. That said, unless the cost of hydrogen relative to electricity decreases significantly - and this is only likely to happen through economies of scale and technological developments - most consumers will see this is a disadvantage for FCEVs. Given the lack of investment in these areas today, it is unlikely that the cost of hydrogen will decrease in the near future. This makes the widespread adoption of FCEVs less likely.

FCEV Benefits

The inefficient energy conversion and higher fuel cell costs associated with FCEVs may be a cause for concern. FCEVs, however, offer benefits and efficiencies that BEVs lack. These include energy density and refueling time.

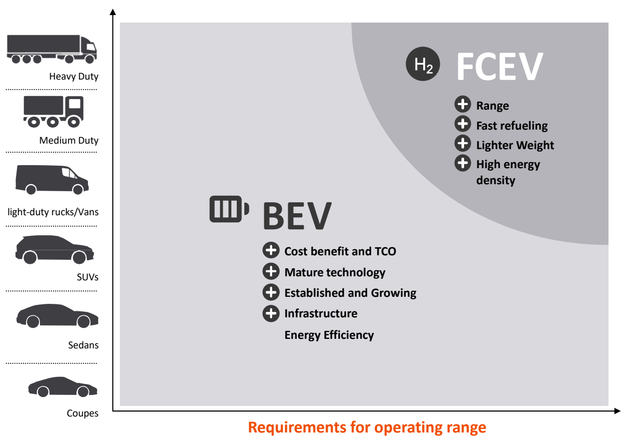
The energy density of stored hydrogen is significantly higher than batteries. This enables FCEVs to carry more energy and weigh less (2 kWh/kg compared to 0.2 kWh/kg) than BEVs. It takes about the same amount of time to refuel an FCEV as it does to refuel an ICEV, which is on average much faster - around six or seven times - than charging a BEV using a DC fast charger. Fuel cell systems also address range and refueling time concerns that have slowed the adoption of BEVs.

FCEVs are particularly suitable for applications requiring high power, large capacity, or long distance travel - uses that are primarily within the medium- and heavy-duty commercial vehicle (MHCV) segment.



Source: Porsche Consulting
Figure 38: Well-to-Wheel efficiency comparison (BEV vs. FCEV)

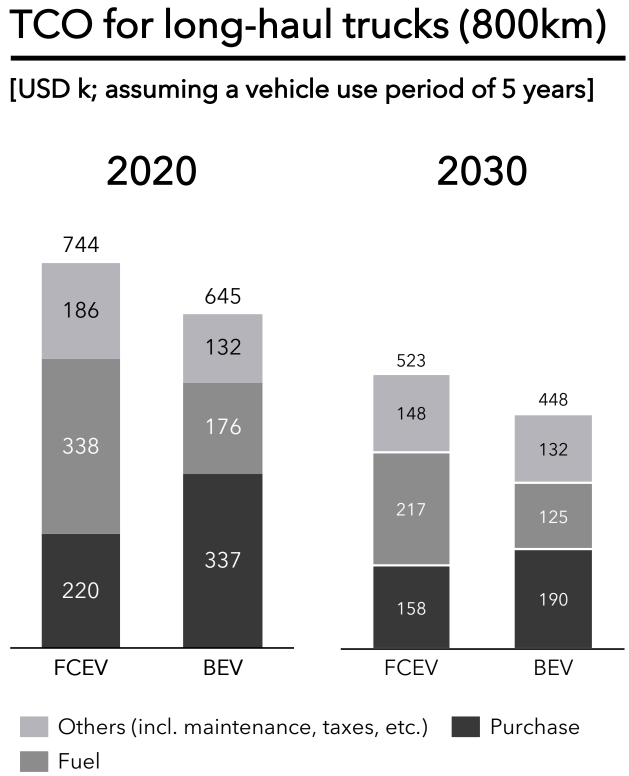
The MHCV sector's bottom line relies on total cost of ownership, operating time, and the ability to move goods as quickly as possible. The longer range and faster refueling times of FCEVs are unlikely to be matched by BEVs - at least in this segment - in the near future. For BEVs to reach parity with the longer-range capabilities offered by FCEVs, larger battery packs will be required, ultimately increasing the weight of the vehicle and potentially jeopardizing payload capacity and weight limits. This gap will narrow, however, with continued investment in the technological advancement of battery energy density. Nevertheless, we see potential for FCEVs in the medium- and heavy-duty commercial vehicle sector (see Figure 39).



Source: e-mobil
Figure 39: Comparison of FCEV and BEV use cases

Total Cost of Ownership

Despite range and payload advantages, FCEVs have yet to reach parity with BEVs from a total cost of ownership perspective. Total cost of ownership within the medium- and heavy-duty commercial vehicle sector can be broken down into two segments: purchasing costs and operating costs. Figure 40 shows that FCEVs will continue to be more competitive in terms of purchase costs but will lag behind BEVs in operating costs over a five-year period. The lack of scale and investment in FCEV technology will continue to limit its competitiveness, especially as more investments are made to improve battery and related EV technologies and infrastructure.



Source: https://www.transportenvironment.org/sites/te/files/publications/2020_06_TE_comparison_hydrogen_battery_electric_trucks_methodology.pdf

Figure 40: Total cost of ownership comparison for a long-haul truck (FCEV vs. BEV)

Infrastructure

Fuel and infrastructure costs are higher for FCEVs than BEVs. Although fragmented, the overall infrastructure landscape related to BEVs is expected to grow at a rate of 38 percent annually through 2025. This supports more widespread consumer adoption of BEVs. The same cannot be said for FCEVs, as too little investment has been made in hydrogen fueling infrastructure. Today, there are only about 540 hydrogen fueling stations in the world, with only 49 in the U.S. and 5 in Canada (three in British Columbia, one in Québec, and one in Ontario). This stands in marked contrast to the number of EV charging stations: 42,335 in the U.S. and 6,062 in Canada.

To compete effectively against BEVs and enable a future for FCEVs, hydrogen fueling infrastructure must expand. That will require hydrogen to be accessible, easily shipped, and profitable. It also requires minimizing the possibility of leakage and reducing the weight and volume of hydrogen storage systems.

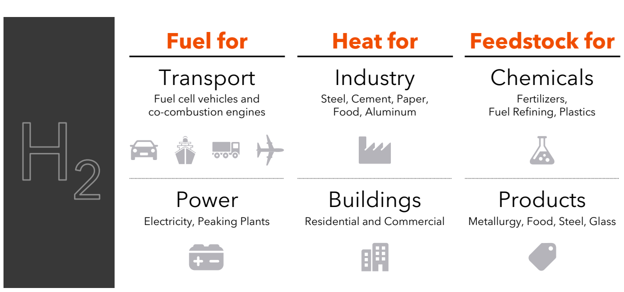
Alternative Applications of Hydrogen

Although FCEVs might not yet be a cost-competitive alternative to BEVs, hydrogen will continue to play a role in the global pursuit of carbon neutrality. Hydrogen can be used as fuel in other parts of the transportation sector (e.g. shipping, aviation) as well as in industrial processes (e.g. steelmaking).

Canada is one of the top ten producers of grey hydrogen in the world. (Grey hydrogen is derived from natural gas and produced from fossil fuels.) It is well-positioned to transition to green hydrogen (produced by electricity generated from renewable sources) in the near future, which will be of substantial benefit for the FCEV industry. Canada currently has one of the lowest production costs of green hydrogen (C$4.50/kg), second only to Chile. Canada can leverage this advantage to become a global leader in the mass production of green hydrogen.

To do so, Canada must first invest and expand renewable energy capabilities in green hydrogen production plants. This will enable Canada to power a variety of non-transportation technologies with hydrogen (e.g. mining and heating).

Figure 41 outlines an opportunity to leverage hydrogen to provide heat, feedstock, and electricity. Under the leadership of NRCan, the Government of Canada recently outlined a strategy to become a leader in the production of green hydrogen. The report Hydrogen Strategy for Canada: Seizing the Opportunities for Hydrogen asserts that by properly leveraging competitive advantages in hydrogen production will allow Canada to create more than 350,000 jobs and generate revenues of C$50B annually by 2050.



Source: Porsche Consulting
Figure 41: Alternative applications of Hydrogen

Opportunities within the FCEV Value Chain

1. Fuel Cell Systems and Components for the MHCV Industry

Canada has a strong footprint in MHCV manufacturing, particularly in coaches and buses. Home to New Flyer Industries, Nova Bus, Lion Electric, and Prévost, Canada offers potential for a supply chain focused on fuel cell systems and components for buses and coaches. The production of fuel cell buses in North America is expected to be limited in the near term and remain relatively small over the long term, with only 1,600 vehicles projected for 2030. Given these low regional volumes, the most significant opportunity may be to export fuel cell systems and components to overseas markets including Japan and China.

2. Partner and Invest in Infrastructure Development to Support the Adoption of FCEVs

The lack of fueling infrastructure is leading to stagnation in the demand for FCEVs. Suppliers could partner with automakers or government agencies to invest in hydrogen fueling infrastructure that caters to the MHCV segment. This is key to expanding the FCEV market. Nevertheless, reaching Canada's goal of one million FCEVs and developing a nationwide fueling network by 2030 will be challenging.

3. Leverage Canada's Leading Position in Fuel Cell Technology Development to Enable Partnerships for Fuel Cell R&D

More than 25 organizations support fuel cell R&D initiatives in Canada. The British Columbia-based Automotive Fuel Cell Cooperation (AFCC) was a fuel stack development joint venture between Daimler, Ford, Nissan, and Ballard Power Systems. The AFCC established an R&D centre focused on developing fuel cell technologies. That led to the establishment by Daimler of the world's first standardized automotive fuel cell stack production facility in the Vancouver area. This facility showcases how Canadian R&D can result in the development of a production facility and help ensure that FCEV targets are met. Suppliers can establish and leverage these types of partnerships to further develop state-of-the-art fuel cell systems for FCEVs. This can open opportunities to supply both domestic and international automakers.

Conclusion

The transition to electric vehicles (EVs) represents a once-in-a-lifetime opportunity to leverage Canada's assets and competitive advantages to increase the economic contributions of an industry that has long been vital to the nation's economic well-being. These competitive advantages include:

- A robust supply chain that includes five automakers and the headquarters of several global automotive parts manufacturers;
- Substantial reserves of minerals used to produce EV batteries:
- A public policy environment that is supportive of EV investments:
- A highly-skilled workforce; and
- Electricity generated almost exclusively from non-fossil fuel sources in most provinces.

Recent announcements confirm that Canada will participate in most elements of the transition to EVs, but much more work must still be done to ensure that the country is a full and significant player in North America's EV supply chain. This involves attracting and securing EV-related investments in existing assembly plants and supporting automotive parts manufacturers during what is expected to be a disruptive transition period. It also involves striking a balance between environmentally and socially responsible mining and manufacturing practices in order to extract and process critical minerals and attracting new investments in battery material, cell, and module production.

There are several other considerations that stakeholders, including policy-makers and industry representatives, should heed. First, it is important that investments in the EV supply chain feature advanced manufacturing technologies, many of which can be developed, manufactured, and integrated by Canadian-based companies. The combination of EV and advanced manufacturing investments can position Canada as a leader in both technologies, and as such, stakeholders should be prepared to support both.

Second, realizing EV-related investments requires collaboration across all stakeholders groups as well as substantial investments in infrastructure, innovation, and talent. These investments may require significant resources in their development phases, but are necessary to ensure that Canada can leverage existing competitive advantages to capitalize on the economic, technological, and environmental benefits associated with EVs over the long-term.

Third, this matter is urgent. The time to act is now. Dozens upon dozens of EV-related investments have been announced over the time that it has taken to complete this analysis, many of which may not come online for several years. Being prepared to support prospective and incumbent investors is vital to building a next generation EV supply chain in Canada.

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