Future of Canadian Automotive Labourforce

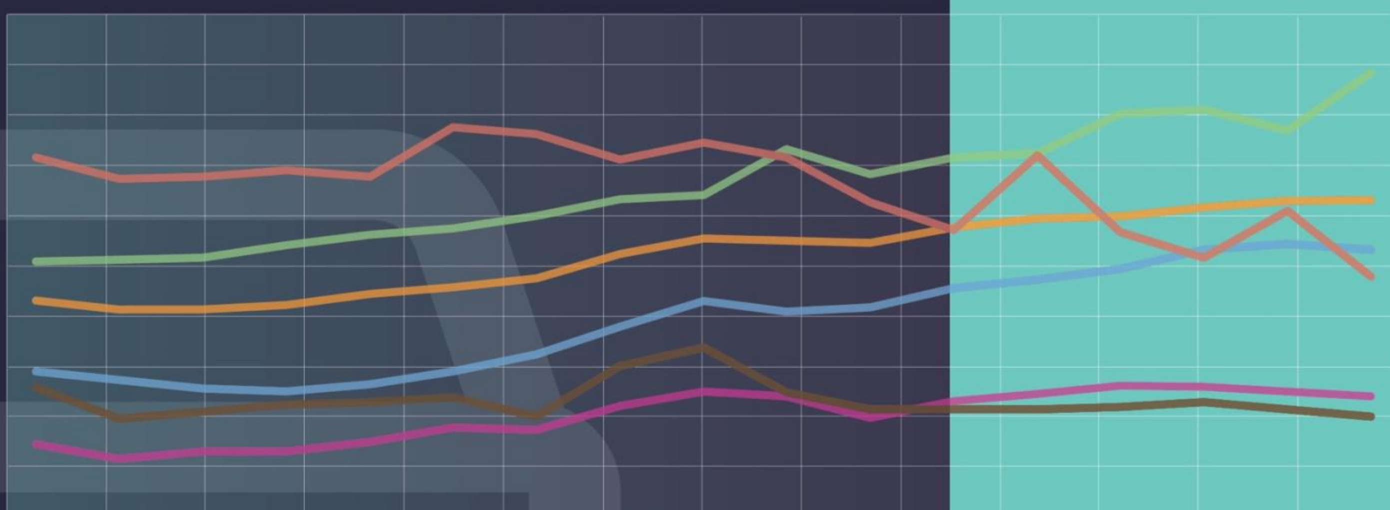
Sur l'avenir de la main-d'œuvre de l'industrie automobile canadienne

FOCAL Initiative

TREND REPORT

AUTOMOTIVE INDUSTRY LABOUR MARKET ANALYSIS

The Impact of EV Production on the Automotive Manufacturing Supply Chain: Sources, Methods and Findings



The project is a collaboration of the Canadian Skills Training and Employment Coalition, Prism Economics and Analysis, and the Automotive Policy Research Centre.

October, 2021

futureautolabourforce.ca

THIS PAPER was prepared for the Auto Labour Market Information (LMI) Project, now known as the Future of *Canadian Automotive Labourforce (FOCAL) Initiative.*

The goal of the project is to help stakeholders better understand the automotive labour market. The Project will create industry-validated, regional, occupational supply and demand analyses and forecasts and skill profiles for skilled trades and other key skilled occupations in the broader automotive sector including vehicle assemblers, parts manufacturers and technology companies that supply the industry. The project will also examine various labour market trends in the sector and facilitate discussions among stakeholders about how to address any forecasted skills shortages and other labour market challenges. The planned outcome of the project is enhanced regional labour market information that will support colleges, employers, policy makers and other stakeholders in taking practical steps to address skills shortages and other labour market challenges in the automotive sector.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Over the span of the FOCAL I project, our research initiative has produced labour market information and followed trends related to Canada's automotive production and technology sector. One of FOCAL's objectives has been to measure the size and impact of changes in vehicle production in Canada. Analysis focused on production, employment and labour markets in specific occupations, industries, regions and provinces. One aspect of the analysis has been the accurate tracking of the supply chain.

Research on the supply chain for automotive production in Canada, during FOCAL I, used a combination of top-down and bottom-up approaches to add depth and insight to existing results. Top-down analysis is based on industry and economic level statistics, analysis and models. Bottom-up analysis is based on a data collected for individual business establishments. FOCAL I findings used measures from both these approaches and provided new evidence on the true size and impact of production of internal combustion engine (ICE) vehicles and related employment.

Over the past few years and following the Paris agreement, numerous governments have set targets for partial or full zero-emission vehicle sales targets from 2030 to 2050. Moreover, the majority of the global automotive OEMs have made announcements and commitments to gradually shift production from internal combustion engine vehicle (ICEV) to electric vehicles (EV) over the upcoming decades. How will these changes impact production, the parts manufacturing industry, and the automotive manufacturing labour force?

This report looks at existing research on how the shift from ICE to EV has and will change the supply chain in Canada and other countries and how available data and approaches can be used to measure the coming change in Canada. The objective is to find the best approach to analyzing one of the major shifts in the history of the automotive manufacturing sector. Results are preliminary and exploratory and consider the best approach for the research in the FOCAL II program.

This introduction is followed by a second section that reviews reports and methodologies applied in Canada and other countries to assess changes in the supply change and the impact on businesses and employment of rising EV production. The third section looks at available top-down methodologies and data to assess the impact in Canada.

The fourth section turns to bottom-up data and the detailed evidence on contrasting EV and ICE components and parts. At this very detailed level of analysis, it becomes clear that some established suppliers in the sector will be dramatically impacted as demand for some parts will disappear, and other suppliers will be partially affected, while entirely new opportunities to produce new parts emerge. The fifth section makes a preliminary attempt to quantify changes in automotive production and employment levels.

This report assists in establishing a methodology which can be used to quantify the impact of such a shift in FOCAL II. In an upcoming study, a measure of the supply chain and inter-industry linkages is essential to accurate impact analysis. Given the rapid change in the supply chain for EVs and ICE vehicles, updating interindustry linkages is essential to understanding the current and expected future state of vehicle production in Canada.

A SURVEY OF THE IMPACT OF EV TECHNOLOGY

This section summarizes ten studies which have assessed the impact of EV production on the automotive industry and its supply chain. Our purpose is to assess the findings and the range of methodologies applied; seeking the best approach for FOCAL II.

FOCAL's analysis is restricted to the scope and impact of manufacturing vehicles, parts and the related supply chain. This review reveals that studies often have a broader focus covering the impact of a range of policies and changes that target climate change and environmental issues. Studies rarely are focused only on the manufacturing sector and labour market impacts. While manufacturing is usually considered, analysis ranges over impacts in many other sectors of the economy. The final assessment of impacts usually adds together positive and negative impacts in all the sectors.

Sectors of the economy covered can include:

a. Energy industry impacts focusing on the price, production and distribution and consumer demand for electricity and fossil fuels.
b. Consumer spending and saving including vehicle purchase and operating costs.
c. Environmental impacts usually measured by GHG emissions.

d. Infrastructure impact related to building electricity generation and distribution systems, including charge stations.
e. Manufacturing impacts including new capacity added across the EV supply chain and, sometimes, the loss of ICE production.

Impact measures cover production levels, imports and exports, government revenues and expenses and employment.

The geographic scope of the reports ranges over:

a. Global
b. European Union
c. National
d. State / Provincial
e. Regional

This report briefly reviews ten impact studies published over the period 1995 to 2020. The studies are presented in chronological order; tracking how added information about EV production has shifted the methodologies and overall conclusions. Findings are used to assess the possible application of each of these methodologies in FOCAL II research.

The following ten studies offer a sample of published analysis of the impact of EV production. The reports provide examples of the application of several methodologies across all the geographic regions and areas of economic impact.

The Impact of electric cars on the U.S. Economy: 1998 to 2005.

This 1995 study was one of the first to estimate economic impacts and it considered separate estimates of manufacturing, energy and operations (consumer) effects. Model based analysis created various scenarios to track the impact of a rising share of EVs across the 1995 to 2005 period. [1]

[1] Meade, D. (1994) The impact of the Electric Car on the U.S. Economy; 1998 to 2005 Inforum *http://www.inforum.umd.edu/services/models/lift.html*

The study's author, Douglas Meade, used the INFORUM LIFT model. This is a large-scale econometric model that covers the traditional macroeconomic measures as well as production and employment details for 85 industries. The model incorporates input-output relationships to track inter industry dynamics. This model is used in subsequent reports and its structure and impact on results is discussed again later.

Findings in manufacturing reflect compositional differences in ICE and EVs manufacturing. The report notes that EVs use more non-metal parts and electrical components. The importance of battery technology and expanded production is incorporated. How this change in the supply chain is incorporated in the model is not explained. Employment losses in manufacturing are reported to be mitigated by the transition of parts manufacturers from ICE to EV components and the assumed higher labour intensity of EV related production. Increased EV and lower ICE production results in some added industrial activity *but the study acknowledges that production in the motor vehicle industry is lower after the switch to EVs and this relates to the mix of parts in the ICE and EV supply chain.*

Calculated losses in manufacturing activity are more than offset by output and employment gains that are attributed to energy and operational benefits – mostly from the replacement of more expensive fossil fuels with electricity. Overall gains in employment across, industries and occupations, are reported in various scenarios for the adoptions of EVs to replace ICE vehicles.

Economic Impact of Electrification Roadmap (2010).

This report by the University of Maryland and Keybridge Research is part of a larger Electrification Roadmap report prepared by the Electricity Coalition.[2] This report uses the INFORUM LIFT model to create alternative scenarios of different policy options over the period from 2010 to 2040. These scenarios report positive economic impacts across manufacturing, energy and operations (consumer) sectors.

Impacts in manufacturing take production shifts from ICE to EVs into account. Results show higher employment in manufacturing as EVs replace ICE vehicles and this is attributed to greater gains in EV component related jobs compared to losses in ICE related parts. Other gains in economic activity are associated with energy markets, an improved trade balance and consumer benefits.

Plug-in Electric Vehicle Deployment in California: An Economic Assessment (2012).

This study focuses on the state economy and considers impacts of increased adoption of electric vehicles across scenarios to 2030.[3] Analysis focuses on the shift in fuel cost and use and impacts in energy production and distribution and on consumer spending. There is no reference to manufacturing impacts and this might reflect the absence of a large vehicle production supply chain in the state. Gains in economic activity are attributed to the switch from more costly fossil fuel transportation to EVs systems.

The model used the "Berkeley Energy and Resources (BEAR) Model" described as a dynamic California Computable General Equilibrium Model for energy and environmental policy analysis.

[2] Electrification Coalition (2010), "Economic Impact of Electrification Roadmap, *https://keybridgedc.com/wp-content/uploads/2013/11/Keybridge-EC-Electrification-Impact-Report-Apr-201* 0.pdf

[3] Roland-Holst, D (2012) Plug in Electric Deployment in California: An Economic Assessment, University of California, Berkeley.

Regional Economic Impacts of Electric Drive Vehicles and Technologies; Case Study of the Cleveland Area (2009).

This regional study is notable for its use of a Regional Input-Output model to estimated local area impacts. Analysis mentions energy and consumer / operation impacts and focuses on economic change related to switching from fossil fuels to electricity. Gains are attributed to consumer benefits from lower energy costs and positive economic impacts are associated with shifting industrial activity across the fuel supply chain.

The study uses the IMPLAN system for the Cleveland region but inputs only energy use and consumer expenditure changes in the impact analysis.

Oregon's Electric Vehicle Industry (2013).

The Northwest Economic Research Center (NERC) define an EV cluster in this study. Recognizing the absence of NAICs industry definitions that represent EV activity, the study created a supply chain. Using the IMPLAN system[4] NERC created a supply chain that spans raw materials, parts suppliers, engineering and design, infrastructure and other support industries. Data for each link in the supply chain was gathered through a survey of corporate suppliers.

Results reported estimates of companies, jobs, value added and tax revenues that were attributed to EV production and its supply chain.

The Economic Impact of Electric Vehicle Adoption in Ontario, Windfall Center, September (2014).

The analysis is applied to three sectors of the economy; the manufacturing, operations (consumers) and infrastructure. Separate impacts are calculated for each sector in Ontario. The impacts are extended to measures of employment by occupations, labour market conditions and supply side responses to expected labour shortages are set out. This appears to be the most specific research undertaken on the impact of EV's in Canada and the conclusions, while dated, may still have a role in forming expectations in government and industry.

[4] *https://implan.com/*

The analysis was done by Econometric Research Limited (Atif Kubursi) using his proprietary "Social Economic Impact Model". Details of the model structure are not offered but measures of multipliers and direct, indirect and induced impacts are presented. The assessment of manufacturing impacts is done by comparing model simulations, of equivalent change of production, of ICE and EV vehicles. Comparing the simulation of a decline in ICE vehicle production against the equivalent increase in EV production provides the gross measures. The difference between the two simulation results is offered as the best measure of net EV impacts.

The report is not clear on how the supply chain is altered in the simulations. The text acknowledges significant differences in technologies including the predominant role of metal products in ICE processes and more electrical and computer-based products in EVs. "Because of this difference in economic and labour market impacts are created."[5] Another important assumption mentioned is that "100% of vehicles adopted in Ontario would be made in Ontario".

The findings for manufacturing show larger positive impacts in all measures in the EV case compared to the ICE case. The positive difference in the impacts is added to other positive impacts associated with EV adoption in operations and infrastructure. These findings are the basis for policy recommendations to promote EVs and the anticipation that "EVs have the potential to dramatically reduce emissions from the personal transportation sector while stimulating the economy."[6]

Impact of Electrically Chargeable Vehicles on Jobs and Growth in the EU (2018).

The European Commission released an assessment of the impact of policy targeting increased production of Electric Vehicles and the related supply chain, as part of its climate policy. FTI Intelligence consulting, in a report for the EU vehicle manufacturers association ACEA, reviewed the findings and analysed them in the context of other research. In particular, FTI Intelligence reviewed engineering research by UBS that prepared a detailed comparison of components and manufacturing processes for EV and ICE vehicles. While the EC analysis has reported a decline in output and employment that would result from replacing the ICE fleet

[5] See "The Economic Impact of Electric Vehicle Adoption in Ontario" Page 51
[6] See page 119

with EV, the FTI report argues that the EC estimates underestimate the true loss of production and employment as EVs replace ICE vehicles.

Specifically, FTI Intelligence reported that:

- Battery Electric Vehicles (BEV) are less labour intensive that Plug in Hybrids Vehicles (PHEV) which are, in turn, less labour intensive that ICE vehicles.
- The EC report does not set out specific assumptions about productions and supply chain differences between BEV and ICE vehicles.
- Using more detailed analysis of EV and ICE components, FTI shows that BEVs have fewer and less complex components and the sourcing of batteries is crucial to assessing economic impacts
- Parts suppliers for the ICE supply chain in the EU will lose more jobs to EV production that the OEMs

This report highlights the need to apply detailed analysis of changes to the supply chain for BEV, PHEV and ICE vehicles to properly measure economic impacts. Once this analysis is added economic impacts show larger output and employment losses from substitution of BEVs for ICE vehicles.

Electromobility 2035 economic and labour market effects through the electrification of powertrains in passenger cars (2019).

This report was prepared at the Institute for Employment Research (IAB), the research institute for the German Federal Employment Agency, and focuses on national measures and impacts. Impact analysis extends over a period from 2020 to 2035 with various scenarios for the substitution of EVs for ICE vehicles connected to German targets for emissions reductions from vehicle transportation.

In the introduction the report noted that while many reports cover the impacts of the substitution of EVs for ICE vehicle, few use advanced and detailed economic models. This report seeks to fill that gap using is the most detailed accounting of supply chain effects available and uses the complex economic IAB/QINFORGE model. The model combines econometric modelling of the national macroeconomy and detailed industry coverage that applies both bottom-up (establishment level data) and top down (Input-Output Table details) in a consistent model framework.

Researchers make many detailed assumptions about the changes that will emerge as EVs replace ICE production. These assumptions are well documented and applied in the specific model relationships. Among the assumptions documented in the report are critical changes to inter industry transactions that reflect the change in the components and supply chain relationships for EV and ICE production. The report makes it clear that many assumptions are based on estimates of changes in the supply chain (and import and export patterns) that have a wide margin of error. Further, these assumptions are needed because the IO table and model industry details is not sufficiently current or disaggregated to track specific EV requirements. Specifically, the report dwells on assumptions about battery technology and sources (imports vs. domestic supply) as critical to the findings.

Scenario results from this complex and detailed analysis confirm the overall conclusion that economic activity and employment will be reduced across the manufacturing supply chain as EVs are substituted for ICE vehicles.

Further this report covers a detailed breakdown for employment by occupations and notes the shift in skills requirements across the transition. Conclusions, on changing skills seem to differ from earlier studies with few cases of higher skill needs.

Quantifying Canada's Clean Energy Economy A forecast of clean energy investment (2019) / Simulating zero emission vehicle adoption and economic impacts in Canada, (2020).

These two reports were prepared by Navius Research in Vancouver for Clean Energy Canada and the International Council on Clean Transportation. Analysis in the first estimates the composition and the size of the “clean energy industry” in Canada and projects production, employment across the industry and economy to 2040. The second extends this research to consider the future of zero emissions vehicles (ZEV) from 2020 to 2040.

The first report is broader in its scope; focusing on the defined clean energy industry covering supply (energy supply, infrastructure and storage) conditions and demand in transportation, buildings and industry. Analysis in this report adapted the Navius gTech model to capture new technologies, consumer preferences and policy impacts. This research treated manufacturing as a source of energy demand and did not consider changes in manufactured products and processes related to environment policy.

In the second report, Navius appears to use the same model to analyse and forecast impacts for a full range of vehicle types (Battery Electric, Plug in Electric, Hybrid, Hydrogen fuel cells). Impacts cover manufacturing, energy production and distribution, consumer purchases, transportation services, infrastructure construction and GHG emissions. The report goes on to consider the economic impact of changes set out in policy scenarios targeting 100% of light vehicle, 50% of medium duty and 15% of heavy duty vehicles sales in 2040.

Navius applies their gTech model to simulate impacts. gTech is described as a general equilibrium model that covers;

- Detailed macroeconomic (National Income Account) measures
- General equilibrium dynamics balancing industry, final demand and labour markets
- Energy supply and demand by fuel type and user markets
- GHG Emissions
- Regional economies.

While reported results indicate gains in manufacturing activity it is not clear in the presentation that impact in manufacturing take losses in the production of ICE vehicles into account. In both reports the size and change in the manufacturing sector is small. Economic gains from clean energy policies and mandated replacement of ICE vehicles for EVs is not explicitly mentioned. These two reports and the gTech model, however, are described as the best available tools for analysis of these policies.

OPTIONS FOR METHODOLOGY

This section reviews methods and approaches which FOCAL might use to analyze changes in the supply chain and the impact of rising EV production.

The ten reports reviewed in the previous section begin in 1995 and end with 2020 research. Observing findings over this time span provides insights into the use of several economic models. In each case the impact analysis in the reports includes a change in the manufacturing sector as automotive production moves from ICE to electric vehicles. This specific manufacturing impact is usually just one of several sector impacts that is considered. The models and methods often take no, apparent, account of changes in the supply chain that will characterize manufacturing. The more recent studies, in particular the assessment of German and European Commission policy proposals, pay specific attention to changes in the supply chain. As these more recent studies add in detailed changes in inter industry relationships in EV and ICE production, the estimates of production and employment losses grow larger.

Most of the studies are applying variations on computable general equilibrium (CGE) models. These models have been built to simulate broadly based and detailed economic change. For instance, the CGE models cover a full range of geography from international trade areas (the EU), nations and regions. These models cover all the macroeconomic measures (e.g. national accounting of final demand), detailed consumer demand, energy supply and use, infrastructure construction, industry supply and demand and import and export flows. Interindustry transactions are usually based on Input-Output table measures of flows but the model tracks changes in industry specific production processes due to relative price change. State and even regional CGE models are mentioned in the research. The Canadian studies by Navius are based on their CGE model. The Windfall Center study for Ontario may be the only exception as it uses a proprietary system that is not described in detail. Results from that study are notably different from others.

Altogether six CGE models are mentioned in the reports. However, it seems that these models, for all their detail and sophistication, do not endogenously create specific changes to inter industry relations and the supply chain for EVs. Such changes need to be entered by the user.

In most of these studies the use of CGE models fits the broad geographic and sector scope expected in analysis of policies that target climate change. Assessing the impact among manufacturing supply chains of EVs was often just on detailed component of the work.

Using a CGE model for FOCAL II work may be desirable in terms of the apparent best practices in the accumulated work on the economic impact of climate change. But to the extent that FOCAL II targets narrower insights related to the automotive production, CGE models may be unnecessarily complex and expensive.

The IMPLAN system, available commercially in the U.S., is a more direct approach that matches up well with the detailed bottom-up analysis described in the next section. IMPLAN is a very detailed data base and model that covers economic measures and industry detail from very small (zip code) to county, state and national areas in the U.S. Models that link that data, in the IMPLAN system, do not contain the behavioural relative price, production function and macroeconomic relationships fund in CGE models. But the IMPLAN has very detailed Input-Output linkages that have been used as the basis for introducing new supply chain links that are needed for EVs. Specifically, the IMPLAN data set has been structured so that users can alter the pattern of sales and purchases with other industries based on new information gathered from other sources. After a first round of new sales and purchases, the IMPLAN has a "normalize" function that rebalances the IO table relationships.[7] This capability and variation of the IMPLAN might be able to use the data gathered for EV production and reported in the next section. IMPLAN, however, is available only for the United States.

Findings reported here, and the model created for FOCAL I, suggest an approach for understanding the impact of EVs on ICE supply chains that could be undertaken in future FOCAL initiatives. In the FOCAL I model the 2015 Statistics Canada Input-Output table was used to create a supply chain model for Canada, Ontario and Quebec. The structural features of this model were limited to the industry linkages reported in the 2015 tables. Based on the methods employed in IMPLAN to alter the US IO relationship in IMPLAN, future FOCAL initiatives should investigate creating a model with the same basic structure but with altered industry linkages, for EV production, build up from the findings in the next section.

CHANGES IN THE VEHICLE WITH THE SHIFT EVS

There are four main variations of electrified vehicles. In this section, we explore these types to highlight the main differences and changes in the vehicle. The differences will be used as a basis in carrying the preliminary bottom-up analysis to assess the implications on the automotive manufacturing supply chain and its labour force.

1- **Hybrid Electric Vehicles (HEVs):** A hybrid electric vehicle (HEV) has a dual engine powertrain system which includes an internal combustion engine (ICE) and an electric traction motor (e-motor). HEVs are equipped with a fuel tank and an auxiliary battery

[7] *https://support.implan.com/hc/en-us/articles/360050717534-Electric-Vehicles-Industry-on-the-Move*

pack to power the vehicle. HEVs primarily rely on propulsion of the ICE and regenerative braking to charge the auxiliary battery through the electric generator, and does not include a charging port for external charging. A power electronics controller in the vehicle manages the flow of energy and makes the decision on whether to allow the ICE, the e-motor, or both engines to propel the vehicle.

2- **Plug-in Hybrid Electric Vehicles (PHEVs):** Plug-in hybrid electric vehicles (PHEVs) have a very similar dual engine powertrain system to that of HEVs, except that PHEVs include a plug-in charging port for external power charging. However, unlike HEVs, PHEVs primarily rely on e-motor and the battery for propulsion. When the vehicle's battery is low on power, the power management system (power electronics controller) of the PHEV switches to the ICE to drive the wheels.

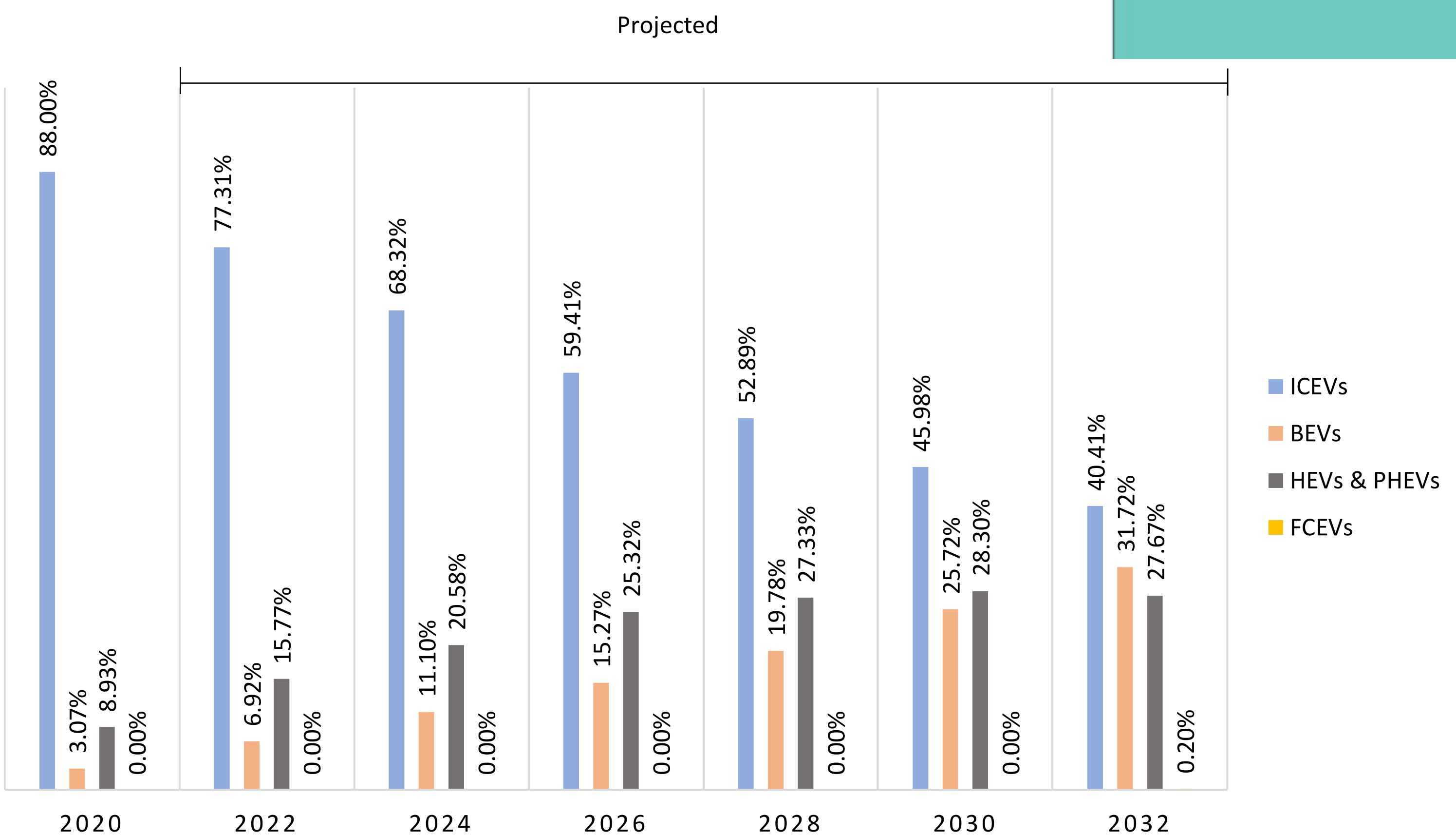
3- **Battery Electric Vehicles (BEVs):** Battery electric vehicles (BEVs), also known as all-electric vehicles, have a fully electric powertrain consisting of a battery pack and an electric traction motor, along with other auxiliary modules and components such as a power management system, a thermal management system, a converter, and an inverter. The battery is the sole source of power in a BEV and is charged through an external power source. BEV batteries are larger than the batteries of HEVs and PHEVs.

4- **Hydrogen Fuel Cell Electric Vehicles (FCEVs):** Hydrogen fuel cell electric vehicles (FCEVs) use a combination of energy sources to power the vehicle. An assembly of fuel cell electrodes (known as the fuel cell stack) uses hydrogen, which is stored in a fuel tank on the vehicle, and oxygen to generate electricity to power the e-motor. An onboard battery pack also provides power to the e-motor, and is charged by the regenerative breaking of the vehicle. A power management system regulates the electricity delivered to the e-motor, providing an optimal performance, and driving experience.

The shift from the traditional ICE vehicle to the electric vehicle is associated with significant changes in vehicle components and parts, mainly the powertrain. While HEV and PHEV powertrains include an ICE as well as an e-motor, the powertrains of fully electric vehicles such as the BEVs and the FCEVs are considerably different from the traditional ICE powertrain. Not only new and unique modules and components to EVs are introduced as part of fully electrifying the powertrain, but a substantial number of parts and components are either eliminated or altered. The implications of these changes extend beyond the vehicle to impact automotive manufacturers and parts suppliers.

In comparing the ICEV to the EV, we use the BEV to showcase the differences in vehicle parts and components. BEVs were selected as they are forecast to be the most common and popular type of EVs in the upcoming years. LMC automotive predicts that by 2030, BEVs will make up around 25% of the global light vehicle sales, and around 46% of all global EV sales. By 2033, BEVs will exceed 55% of all global EV sales. Moreover, as automotive OEMs commit to an all-electric and emissions-free future with timelines ranging between 2035 and 2040, it could well be that the ICE along with ICEVs, HEVs and PHEVs are phased out in the decades ahead. As for FCEVs, while their design offers an innovative, clean and fully electric drive system, it is forecast that the global sales of FCEVs in 2030 will be relatively negligible to the sales of light EVs (less than 0.5% of global light EV sales).

Figure 1. Forecast Global New Vehicle Sales by Vehicle Type (2020 - 2032)



Source: Interpolated from LMC Automotive Light-vehicle global light vehicle sales

Firstly, we start by summarizing the major powertrain automotive systems and group components of ICEVs and BEVs. In doing so, we utilize a combination of references and sources which have conducted vehicle breakdowns and analyses of comparing ICEVs to BEVs. This includes studies such as UBS Group's "Evidence Lab Electric Car Teardown - Disruption Ahead?", McKinsey & Company's "Electromobility's Impact on Powertrain Machinery", Marklines "Vehicle Teardown Reports", and several other automotive-related studies and sources. Table 1. lists the major automotive systems and group components of ICEVs and BEVs.

Table 1. Main differences between the ICEV and BEV components and parts

ICEV Components and Systems	BEV Components and Systems
Internal Combustion Engine	**Electric Traction Motor**
Cylinder Block & Head	AC Induction Motor (OR) DC Permanent Magnet Synchronous Motor
Pistons & Connecting Rods	Rotor & Magnets (Only DC)
Crankshaft & Flywheel	Stator
Valve Train	Cooling Duct
Fuel Injection System	**Powertrain Thermal Management**
Air/Fuel Management System	Radiator
Spark Ignition System	Radiator Reservoir Tank, Pump & Hose
Engine Oil Lubricating System	**Inverter / Converter**
Engine Control Unit - ECU	**Electric Drive Module (EDM)**
Engine Battery & Charger	**Power Distribution Unit (PDU) / ECU**
Engine Cooling System	**DC/DC Converter**
Radiator	**Onboard Charger**
Cooling Fan	**Li-ion Battery Pack**
Radiator Reservoir Tank, Pump & Hose	Li-ion Battery Cell
Fuel System	BMS - Battery Management System
Fuel Tank	Battery Thermal Management (Pump & Coolant Tank)
Fuel Pump	All other pack content
Fuel Filter & Line	**High Voltage Cables**
Exhaust System	**Charging Cord**
EGR Valve	**Transmission / Gearbox**
Exhaust Manifold & Pipe	
Exhaust Catalytic Converter	
Muffler & Tail Pipe	
Transmission	
Differential	

The list above highlights a few major technical differences between ICEVs and BEVs. Some main takeaways from the list are:

1. The ICE is more complex than an electric traction motor, and requires a higher number of auxiliary systems to operate.
2. The ICE and its systems contain a higher number of individual parts and components compared to an electric vehicle motor.
3. The ICEV's powertrain involves more mechanical components (moving parts) than a BEV. The BEV's powertrain includes more electrical and electronic components than an ICEV.
4. There is a significant number of automotive systems, components and parts which are eliminated from the vehicle with the shift to BEVs, especially in the vehicle's engine and the drivetrain. A number of new systems and components (especially electrical and electronic) is introduced to the vehicle with the shift to fully electrified powertrains.

To further examine the differences between ICEVs and BEVs, we use Marklines' Parts Classification database which comprises more than 850 automotive parts and components. Marklines' Parts Classification database provides a detailed breakdown of the vehicle's systems and group components. This additional extensive analysis will assist in conducting a bottom-up analysis of the Canadian automotive manufacturing sector which will identify the automotive manufacturing companies and facilities which will be impacted by a component elimination or change with the shift to electrified vehicles.

In conducting the technical comparative analysis, we start by categorizing the ICEV components into four main groups:

1. *Unaltered Component:* Part or component which exists in an ICEV, as well as in a BEV.
2. *Eliminated Component:* Part or component which is unique to an ICEV and does not exist in a BEV.
3. *Slightly Altered Component:* Part or component which has a similar function in an ICEV as well as in a BEV, however, is slightly altered to fit in a BEV
4. *Optional BEV Component:* Part of component which exists in an ICEV however, it's role and presence in a BEV is optional. 2

Table 2. Forecast Global New Vehicle Sales by Vehicle Type (2020 - 2032)

Main Automotive Component Category	Unaltered	Slightly Altered	Optional	Eliminated
Engine	6	3	14	97
Exhaust System	0	0	0	16
Fuel System	0	0	0	14
Drive Train (Transmission & Differentials)	4	8	5	38
Suspension / Steering / Wheel	56	3	0	0
Axle	34	5	0	0
Total	100	19	19	165

As for the EVs parts, by examining the list of components and parts, we find that a total of 41 new parts and components are introduced with the shift to BEVs. The majority of the parts and components fall under the electrical or electronic category with very minor mechanical role.

IMPLICATIONS ON THE AUTOMOTIVE MANUFACTURING SECTOR AND ITS LABOUR FORCE: A PRELIMINARY BOTTOM-UP ANALYSIS

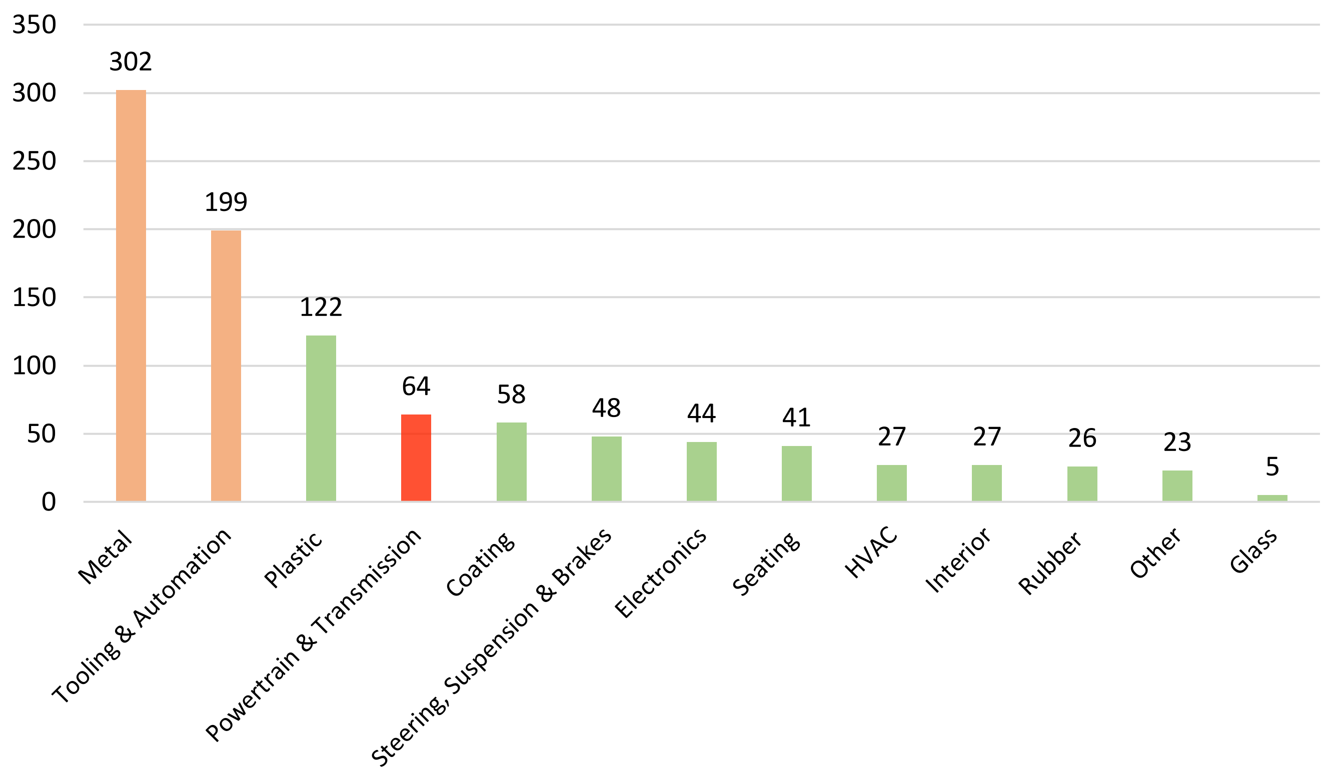
The change in vehicle parts and components associated with the transition to fully electric vehicles will be also accompanied with a disruption to the role and manufacturing operations of a number of automotive manufacturers within the supply chain. While OEMs will have to alter and adjust some manufacturing processes across their production line with the introduction of new EV models, automotive parts suppliers will also have to modify some operations and adapt to the changes. However, since some of the changes in the vehicle and its parts are major, especially with the shift to fully electric powertrains, the role of some automotive supplying companies will be entirely impacted as some components will not be part of a BEV. For example, as presented in table 2. above, a BEV does not have an exhaust system and therefore, a company supplying exhaust system parts (e.g., exhaust pipe, catalytic converter, muffler, and other exhaust parts) will lose business if the ICEV models it supplies for are phased out. Similar implications are expected for facilities supplying ICE parts (e.g., piston, crankshaft, cylinder block…) and/or other ICEV-unique components.

In 2019, around 46% of the parts produced in Canada (CAD 17.59 billion) were exported to the US[8]. Given this strong supply chain integration between the US and Canada, the impact on Canada's automotive manufacturing sector is dependent on the shift to manufacturing electrified vehicles on both sides of the border. Therefore, the shift in the Canadian assembly plants, as well as the US assembly plants will impact the production of certain vehicle parts manufacturing companies.

This impact on the automotive manufacturing companies and facilities within the Canadian automotive manufacturing sector is expected as the OEMs shift to manufacturing fully electrified vehicles mainly in Canadian and US assembly plants. Canada's automotive parts manufacturing industry consists of more than 950 automotive parts manufacturing facilities, among which around than 300 facilities fall under the NAICS 3363 code (Motor vehicle parts manufacturing). However, following FOCAL's definition of the broader automotive manufacturing sector, we include other primary automotive suppliers (e.g., metal, plastic, glass suppliers) in the preliminary impact analysis. Figure 2 presents the distribution by component category of the automotive parts manufacturing facilities within Canada's automotive manufacturing sector. The colors in the chart represent the extent of the impact of the shift to BEVs manufacturing on the operations of parts manufacturing companies. Red represents a high impact level, where most, if not all companies in the category are impacted. On the other hand, green represent a low impact level where very few or none of the companies in the category are impacted by the shift. Categories in orange (moderately impacted) have a significant number of companies impacted by the shift however, this share of impacted companies does not constitute a majority. Note that this impact only covers the four forms covered above and does not examine potential expansion in current operations or demand for specific parts or components.

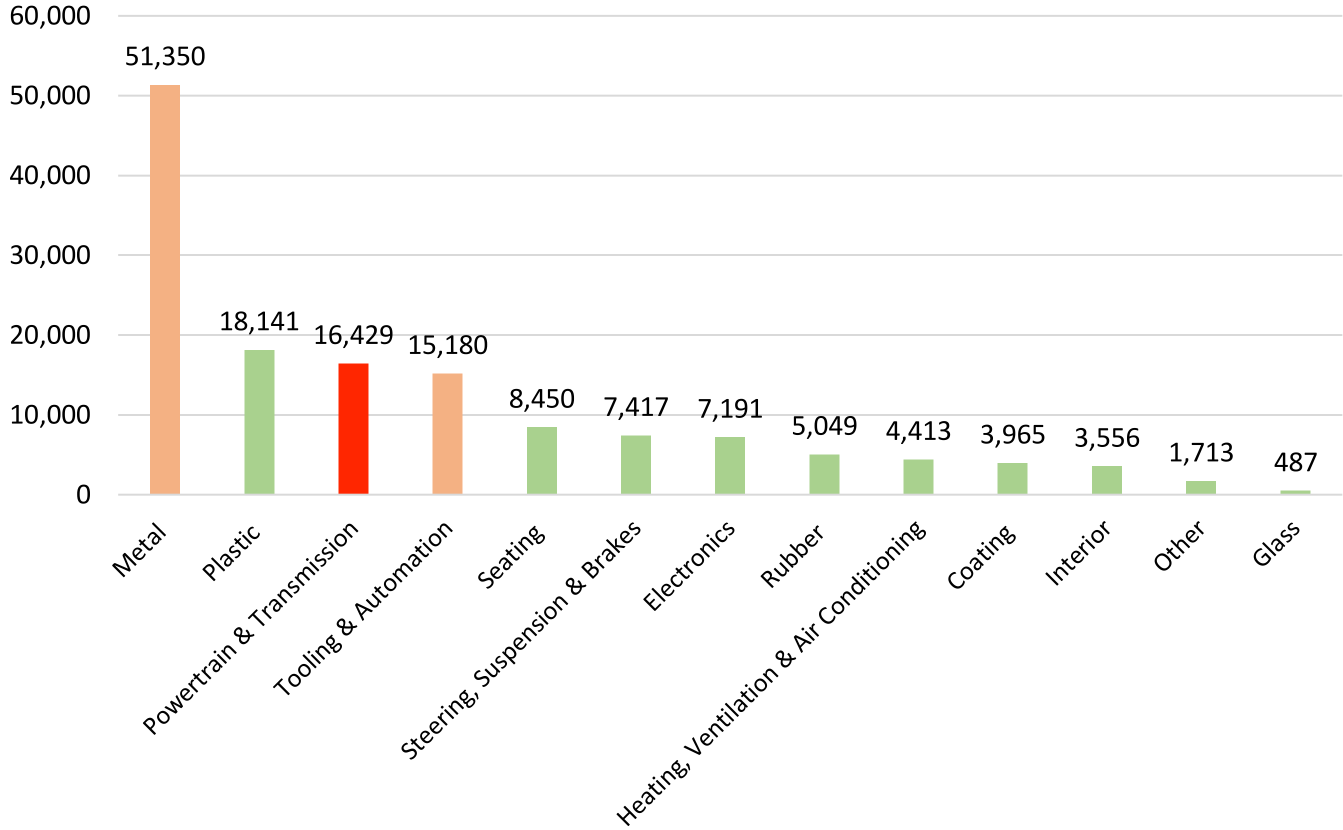
[8] Trade Data Online - Import, Export, and Investment - Innovation, Science and Economic Development Canada

Figure 2. Distribution of Vehicle Parts Suppliers by Component Category



Based on the list of 950 automotive parts manufacturing facilities in Canada, we find that 64 powertrain and transmission manufacturing facilities will be impacted by the shift based on the list of parts they manufacture. Metal manufacturers, as well as tooling and automation are moderately impacted categories with 501 facilities within the two groups. As for the impact by employment count, we find that 66,530 jobs fall within the moderate impact category, while 16,429 are within the high impact group. The distribution of employment by component category is presented in Figure 3.

Figure 3. Distribution of Employment by Component Manufacturing Category



While this analysis is preliminary and provides some initial insight into the impact of the transition to the production of electric vehicles on the Canadian automotive manufacturing supply chain, a more thorough bottom-up analysis of the database of parts manufacturing facilities could deliver a clearer breakdown of the impact of this shift during future FOCAL initiatives. More importantly, it is possible to determine the precise extent of the impact by establishment given that the database includes a comprehensive list of products and parts produced by each facility, as well as the processes and operations employed in manufacturing.

CONCLUDING REMARKS

This shift to vehicle electrification is accompanied by significant changes to the traditional vehicle, especially to the vehicle's powertrain. With the lower complexity of numerous systems in the vehicle, fewer parts are required and thus, a number of vehicle parts manufacturers will be affected by this shift in production. This, in turn, will translate to implications on the automotive manufacturing workforce and its occupations. These implications may also extend to alter some skills which are relevant in the sector. This report provided a preliminary scan of the studies and methodologies to quantify the impact of the shift to EVs production on the automotive manufacturing labour force. The report also looked into the differences between the traditional internal combustion engine vehicle and the new electrified vehicles to perform an early bottom-up analysis of the impact on individual parts supplying facilities and on employment. Future FOCAL initiatives may utilize the methods suggested above to further explore this impact, and offer a comprehensive breakdown of the impact of this shift on Canada's automotive manufacturing sector.

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