THE SHIFT TO EV PRODUCTION IN CANADA'S AUTOMOTIVE MANUFACTURING SECTOR

ASSESSING THE ECONOMIC AND LABOUR MARKET IMPACTS

FEBRUARY 2024

About the FOCAL Initiative

The Future of Canadian Automotive Labourforce (FOCAL) Initiative, funded by the Government of Canada, is a collaboration of the Canadian Skills Training and Employment Coalition (CSTEC), the Automotive Policy Research Centre (APRC) and Prism Economics and Analysis.

The FOCAL Initiative has produced labour market information and data related to Canada's automotive manufacturing sector, examined key trends affecting the automotive labour market, and produced forecasts of supply and demand for key occupations in the broader automotive sector.

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Executive Summary

Canada's automotive manufacturing sector, a key driver of the country's manufacturing and economic growth, is undergoing a significant shift towards zero-emission vehicles (ZEVs) production, aligning with domestic and global efforts to reduce carbon emissions and achieve net-zero by 2050. The move from producing internal combustion engine vehicles (ICEVs) to electric vehicles (EVs) in Canada's automotive manufacturing sector presents both opportunities and challenges. The shift offers the opportunity to develop new domestic supply chains, expand existing manufacturing capabilities, and grow the economic contribution of the sector. However, it poses multiple challenges to the sector and its supply chain including the need to adapt manufacturing processes, manage the fluctuating demand for components, and transition the workforce across industries and sectors. Industry stakeholders must also navigate the considerable uncertainties and risks of this transition.

This transition, and its significance to Canada's economy, is the focus of this comprehensive report which analyzes its impacts from 2025 to 2040, offering insights to policymakers and industry stakeholders on the potential economic and labour market implications. This report presents detailed analysis of the shift to EV production, particularly battery electric vehicles (BEVs). This involves careful review of the automotive and battery manufacturing supply chains, including the announced plans for new production operations and related changes reaching upstream to chemical manufacturing, mineral processing and mining potential. In addition, the analysis tracks the related decline in assembling ICEVs and the shrinking demand for their components, the parallel aspect of this transition. The timing and magnitude of new production and shifts in the supply chain have been set out in three scenarios that reflect the various potential future outcomes – from rapidly growing BEV production capabilities depicting a successful shift in production over the upcoming years, to a more gradual shift in vehicle production, accounting for the various risks and barriers to EV production and adoption. The EV production analysis estimates specific output and employment changes expected across the different stages of the supply chain. Each scenario presents a multi-layered economic impact:

1. In scenario 1, greater EV consumer acceptance is assumed, with continued success in winning production mandates, in producing and processing rare earth minerals domestically, and in manufacturing EVs and their batteries. In this scenario, significant economic expansion and job market boost is projected, with an output increase of over $50.0 billion by 2040, and nearly 100,000 net jobs created by 2040.

2. Scenario 2 assumes slower consumer acceptance of EVs, translating to a more gradual transition in EVs manufacturing and lower batteries production, which is further accompanied by

less success in developing domestic rare earth mining capabilities, and in securing production mandates. These assumptions project a modest economic impact, with an overall output increase of $2.4 billion and approximately 4,250 jobs added by 2040, but also indicate initial job and economic losses in the first years of the transition.

3. Scenario 3, combining assumptions of scenarios 1 and 2, predicts output reaching $13.3 billion and 27,000 jobs added by 2040.

These scenarios highlight the variable impacts of Canada's transition to EV production on economic output and employment across various industries and the overall economy. Most notably impacted is the gasoline engine manufacturing industry as a result of the weakening demand for ICEV-specific components, a factor of declining domestic ICEV production and exports of ICE components. On the other hand, battery manufacturing, along with industries within its supply chain, are set to gain the most (in output generated and jobs created) as a result of the start up of battery manufacturing operations and its related activities.

While several risks, barriers and challenges may impede the shift in production and adoption of EVs, the successful transition to EV production requires coordinated efforts from industry and government to minimize impacts, and ensure the smooth transition of the workforce.

Introduction

Over the past decades, Canada's automotive manufacturing sector has played a significant role in driving the country's economic growth and industrial development. The sector employs around 210,000 workers, contributes over $19 billion to Canada's GDP, and accounts for more than 8% of the Canada's overall exports[1,2,3]. Given the importance and role of automotive manufacturing in Canada's economy, fluctuations in production levels, as well as changes in the supply chain, trade and product technology can have wide-ranging direct and indirect implications, which can translate across numerous industries and sectors. These impacts can potentially lead to significant changes in the output and employment of automotive manufacturing, its supply chain, as well as the entire economy.

The automotive sector is currently experiencing a significant transition towards zero-emission vehicles (ZEVs), a trend that is rapidly gaining traction with the ongoing decarbonization efforts across multiple industries and sectors. These efforts are aligned with the global objective of achieving net-zero carbon emissions by 2050, with commitments to environmental sustainability and a shift towards renewable energy sources and cleaner technologies[4]. Since the early 2010s, sales of electric vehicles (EVs)[5] in Canada and the United States (US) (Canada's main vehicle exports destination) have shown significant growth. In 2022, 205,000 new EVs were registered in Canada, making up 13.6% of total vehicle registrations for that year[6]. In the US, EV sales made up 12.3% of the country's total new vehicle sales in 2022[7].

For Canada's automotive original equipment manufacturers (OEMs), the shift towards EVs is also a strategic move to remain competitive in the regional and global markets. Canadian automotive manufacturers are increasingly investing in the development and production of EVs, their technologies and components, recognizing the growing consumer demand, as well as the potential for significant market growth in the upcoming years. These investments have been supported by government incentives and policies aimed at boosting the domestic production and adoption of ZEVs[8].

The transition to EVs certainly presents both opportunities and challenges for Canada's automotive manufacturing sector. It offers Canada a chance to lead in a rapidly evolving industry, driving innovation, attracting investment and winning production mandates, developing a

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[1] FOCAL Initiative (2021). *Importance of the Canadian Automotive Manufacturing Sector.*
[2] Statistics Canada (2022). *Gross Domestic Product by Industry (Monthly)*.
[3] Industry Canada (2022). *International Trade Data and Market Intelligence*.
[4] Government of Canada - Environment and Natural Resources (2023). *Net-zero emissions by 2050*.
[5] In this report, electric vehicles (EVs) refer to hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs).
[6] Statistics Canada (2023). *New Motor Vehicle Registrations*.
[7] Marklines Automotive Data (2023). *Automotive Yearly Sales by Country*.
[8] Federal Economic Development Agency for Southern Ontario (2023). *Government of Canada supports manufacturers and electric vehicle supply chain across Ontario.*

domestic supply chain, and creating new jobs. The rise in EV production opens up new markets for Canadian automotive parts manufacturers, potentially increasing the country's exports. It also encourages partnerships with tech firms in areas such as electronics and battery technology, fostering an ecosystem of innovation. Moreover, this transition in both production and adoption aligns with global environmental goals, which enhances Canada's role and reputation in sustainable practices.

The transition to EV production also requires significant adjustments in manufacturing processes, supply chain, and the workforce as EVs, and more specifically battery electric vehicle (BEV) powertrain systems, are fundamentally different than those of internal combustion engine vehicles (ICEVs). Traditional automakers must adjust their production lines to adopt new manufacturing techniques, accommodate new processes, and potentially reconfigure the production floor layout to produce EVs. This includes processes like battery pack assembly, battery cell and module production, and electric motor integration, all fundamentally different from those in ICEV manufacturing.

The transition to EV production in automotive manufacturing faces significant challenges and uncertainties related to a wide range of factors potentially impacting production and adoption. These risks and barriers may be directly or indirectly linked to vehicle and battery production, and may include vehicle and battery technology limitations, charging infrastructure-related constraints, automotive and battery supply chain disruptions, and market-related challenges influenced by consumer preferences and economic trends. For example, consumers may have concerns about operating EVs in extreme cold, their range, and the availability of charging stations, all potentially slowing down this transition[9]. Policy and regulatory uncertainties can also have a profound impact, affecting EV production and adoption, and shaping industry standards and compliance requirements. These risks and barriers may individually or collectively hinder the transition in the production and adoption of EVs.

With the shift to EV production, even more fundamental changes are expected to occur in the automotive manufacturing supply chain. The supply chain, which includes a broad range of component and parts manufacturers, and extends to raw materials mining and production, must adapt to meet the specific demands of EV manufacturing. This adaptation involves a shift from sourcing parts from the traditional ICEV supply chain such as internal combustion engine (ICE) components, exhaust systems, and fuel tanks towards those required for EVs, such as batteries, electric motors, and power control units. A report by UBS detailing the differences between ICEVs and BEVs estimates that over 50% of BEV components[10] are sourced from outside the traditional automotive manufacturing supply chain[11]. Despite being less mechanically complex, an EV, and more specifically a BEV, has a higher electronic complexity, with some of its key components sourced directly from the chemical manufacturing industry[11].

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[9] Consumer Reports (2024). *How Much Do Cold Temperatures Affect an Electric Vehicle's Driving Range?*
[10] Tier-1 supplier components; measured by value.
[11] UBS (2017). *UBS Evidence Lab Electric Car Teardown – Disruption Ahead?*

The move to producing EVs introduces a core segment in the automotive manufacturing supply chain which is the battery manufacturing supply chain. The battery, which is a main component of the EV powertrain, represents a significant shift in the sourcing and production strategies of automotive manufacturers. Battery production requires the integration of chemical, electronic, electrical and metal manufacturing processes, a departure from the traditional mechanical focus of automotive manufacturing. This necessitates establishing partnerships and securing supply agreements that extend beyond the scope of the traditional automotive supply chain with specialized battery and chemical manufacturers, as well as mining companies.

The introduction of new components, suppliers, and industries into the automotive manufacturing supply chain as the industry transitions towards EV production, along with the shift away from ICEV-specific components implies significant changes and implications to the industry's output and employment. On one hand, the rise in EV production will lead to an increase in employment and economic activity in industries and sectors directly and indirectly associated with battery manufacturing, as well as electrical and electronic component production. This may also be accompanied by a shift in skill requirements in automotive manufacturing. On the other hand, this shift away from ICEV production will also lead to a decline in the output, as well as job losses in industries related to ICEV manufacturing. Suppliers in these industries may be directly or indirectly impacted by the move away from ICEV production.

Since 2020, several OEMs, battery manufacturers, and automotive parts suppliers have announced substantial investments and production plans related to EVs, batteries, and EV components in Canada[12]. As Canada's automotive manufacturing sector gradually transitions towards EV production, the implications of this shift are expected to significantly affect the sector, its supply chain, the labour force, and the overall economy. This highlights the need for a comprehensive analysis and forecasting to quantify the changes and implications of this transition.

This report provides an in-depth analysis and forecast of the changes and implications of Canada's automotive manufacturing sector's transition towards EV production. Covering the period of 2025 - 2040, the report examines the impacts of shift in production and investment in EV and battery manufacturing within Canada's automotive and battery manufacturing supply chains.

The analysis in this study is structured around various scenarios that explore different potential outcomes of this transition. These scenarios are designed to capture a range of outcomes in automotive and battery manufacturing, ranging from an aggressive shift to a more measured, gradual transition in EV and battery production. The scenarios also account for potential uncertainties and risks in the vehicle and battery manufacturing supply chains, as well as other challenges which may impede the transition in production. By examining the outcomes of these scenarios, the report aims to highlight the potential economic and labour market implications of

[12] Invest in Canada (n.d.). *EV Supply Chain*.

the transition to EVs. The report also presents the broader impacts of these changes on the Canadian economy. It considers the potential for new job creation and growth in economic output.

The analysis presented in this report aims to inform policymakers, industry stakeholders, and government of the potential impacts, challenges, and the opportunities presented by this shift in automotive manufacturing. By offering a detailed analysis and forecast, the report provides stakeholders with important insight, highlighting both the potential risks and the opportunities that arise from the move towards EV and battery production.

Background

The FOCAL Initiative assists employers, workers, and job seekers in navigating labour market challenges. In addition to direct assistance through wage and training subsidies, FOCAL has been offering guidance in critical areas such as skills transferability, diversity, immigration and apprenticeship. The transition from ICEV to EV production in Canada's automotive manufacturing sector is expected to be a key area of focus over the upcoming years.

In 2021, the FOCAL Initiative released a report titled "The Impact of EV Production on the Automotive Manufacturing Supply Chain: Sources, Methods and Findings"[13]. The report was part of FOCAL's preliminary efforts to assess the impact of the shift to EV production on Canada's automotive manufacturing supply chain. Its analysis estimates that approximately 16,000 jobs and 64 companies are at high risk due to the transition towards EV production. The report also acknowledges the potential output and job gains in EV and battery-related manufacturing activities. It explored the best methods to quantify the broader impacts of the transition from ICEV to EV production on Canada's automotive manufacturing sector, its supply chain, and the economy.

As automotive manufacturing is interlinked with numerous other sectors and industries, the economic and labour market impacts can include direct, indirect, and induced effects which can affect a wide number of these sectors and industries. For this reason, there was a need to methodologically measure the impacts of this transition which may lead to substantial shifts in labour markets, industrial outputs, and supply chain structures. In FOCAL's initial report, the Input-Output (I-O) method was identified as a more accurate tool for this purpose, capable of capturing the multi-layered effects of the transition on various economic sectors and industries.

Recent investment announcements to expand Canada's EV and battery manufacturing capabilities underscore the importance of such analysis, especially as the transition in production is already underway. In recent years, alongside Toyota, which has been assembling hybrid vehicles in Canada, Ford, General Motors (GM), and Stellantis have announced plans to retool and

[13] FOCAL Initiative (2021). *The Impact of EV Production on the Automotive Manufacturing Supply Chain: Sources, Methods and Findings*.

upgrade their Canadian production lines for EV manufacturing. Notable battery manufacturing announcements also include the NextStar battery production plant in Windsor (a partnership between Stellantis and LG Energy Solutions), VW's battery manufacturing facility in St. Thomas, and GM and Ford's battery material manufacturing plants in Quebec[14]. Other material processing and mining announcements have also accompanied Canada's growing EV and battery manufacturing capabilities. A select number of automotive and battery manufacturing investment announcements are highlighted in Appendix A.

Vehicle Types & Powertrian Technologies

Understanding the technical and price structure differences between ICEVs, HEVs, PHEVs, and BEVs is crucial to estimating and forecasting the economic and labour market impact of the shift from ICEV to ZEV production. Each vehicle type represents a different technological approach, includes different powertrain parts and components, and has specific manufacturing requirements, impacting the demand for specific parts and components, and subsequently influencing the broader automotive manufacturing supply chain dynamics. This shift not only affects the types of components needed, but also the occupations and skills required for their production in both vehicle assembly and vehicle parts manufacturing. For instance, the increased focus on battery technology and electric motors in BEVs requires specialized skills in electrical engineering and battery chemistry, diverging from the traditional mechanical skills dominant in ICEV production.

ICEVs are powered by internal combustion engines that run on conventional fuel sources such as gasoline or diesel. The key components of an ICEV include the engine, transmission system, fuel injection and storage system, and exhaust system. The combustion of fuel in the engine's combustion chambers generates power that is transmitted to the wheels through a complex transmission system. This process involves numerous mechanical parts, including pistons, valves, crankshafts, and gears[15].

HEVs combine the traditional ICE with an electric propulsion system. This dual-system includes a smaller ICE, an electric motor, a small battery pack, and a regenerative braking system. The vehicle can alternate between or simultaneously use the combustion engine and electric motor for propulsion. The battery in an HEV is charged through regenerative braking and the ICE, not requiring external charging. HEVs are more complex than ICEVs due to the integration of both electrical and mechanical systems[16].

PHEVs take the hybrid concept further by featuring relatively larger battery packs compared to HEVs, that can be charged externally, allowing for an all-electric driving range. PHEVs have both an electric motor and an ICE, like HEVs, but with the ability to plug in and charge the battery. This

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[14] Canadian Vehicle Manufacturers' Association (2023). *State of the Canadian Automotive Industry*.
[15] U.S. Department of Energy - Alternative Fuels Data Center (n.d.). *How Do Gasoline Cars Work?*
[16] U.S. Department of Energy - Alternative Fuels Data Center (n.d.). *How Do Hybrid Electric Cars Work?*

allows PHEVs to drive for extended distances using only electric power, switching to the combustion engine as the battery energy depletes. The technical complexity in PHEVs is in the sophisticated energy management system that efficiently balances power between the electric motor and the ICE[17].

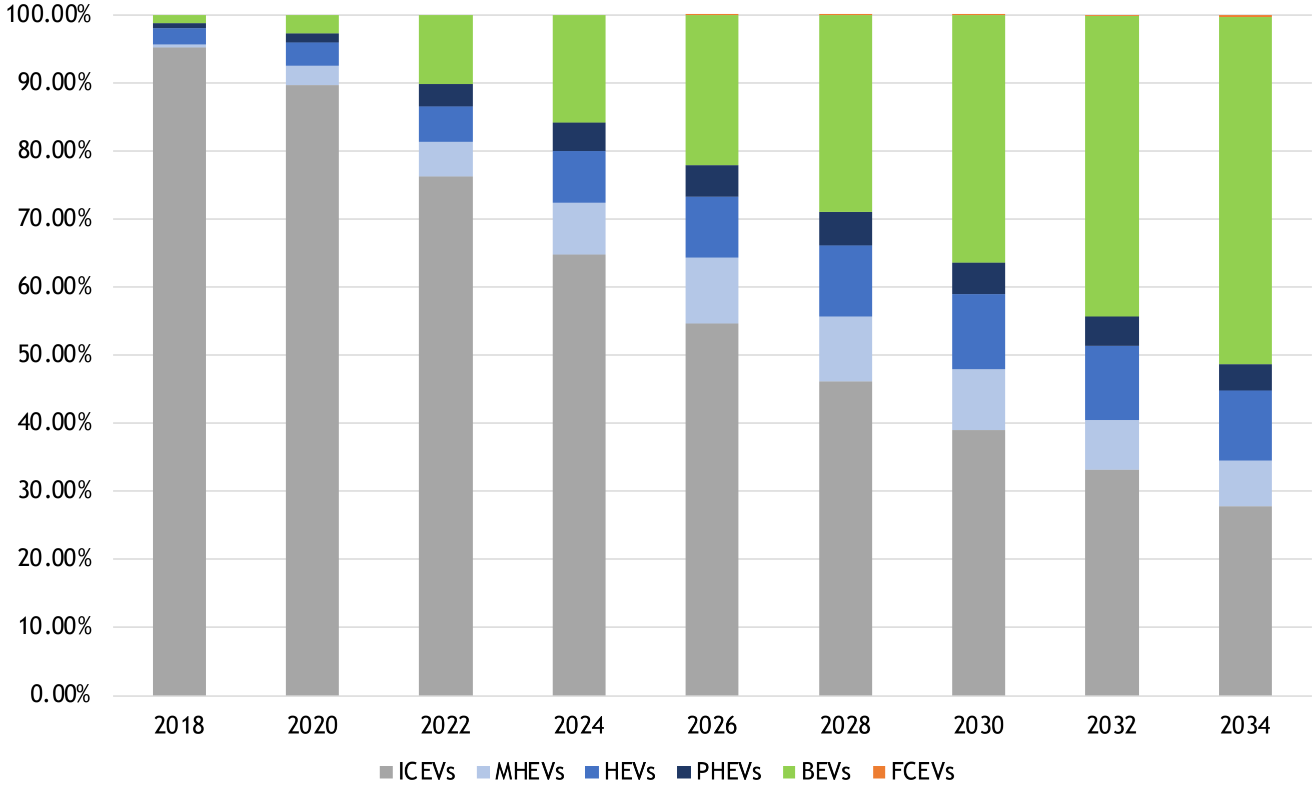
The powertrain of a BEV represents a significant shift away from ICEVs and hybrids. BEVs are solely powered by electric motors and do not have an ICE, a fuel tank, or an exhaust system. The major components of a BEV include a high-capacity battery pack, one or more electric motors, and a system of power electronics including a power control unit, an inverter, and an onboard charger. BEVs are mechanically simpler compared to ICEVs, but require more advanced electronic systems and technologies to operate. The absence of an ICE, along with a simpler transmission system reduces the mechanical complexity of a BEV, leading to different manufacturing and maintenance requirements[18].

With the global aim of achieving low or net zero emissions in the future, ICEVs are expected to be mainly replaced by BEVs, with hybrids serving as a transitional technology. Figure 1 demonstrates the fundamentally different powertrains of an ICEV and BEVs. As technological advancements in battery efficiency and charging infrastructure continue, and as battery prices continue to decline with increased scalability, BEVs are expected to increasingly become the primary choice for personal transportation. This shift is anticipated to position BEVs ahead of hybrid vehicles, particularly in terms of their environmental advantages and their ability to deliver cost savings over the long term. This is depicted in the global forecast of light-duty vehicle sales in Figure 2.

Figure 1. ICEV vs. BEV powertrain

[17] U.S. Department of Energy - Alternative Fuels Data Center (n.d.). How Do Plug-In Hybrid Electric Cars Work?
[18] U.S. Department of Energy - Alternative Fuels Data Center (n.d.). How Do All-Electric Cars Work?

Figure 2. Projected global light-duty vehicle sales by powertrain type



Source: Marklines - GlobalData Automotive Sales Forecast

The EV & Battery Manufacturing Supply Chains

The FOCAL Initiative had previously demonstrated the size and importance of Canada's automotive manufacturing sector and its supply chain. FOCAL defined automotive production in three main segments: Vehicle Assembly, Vehicle Parts Manufacturing, and Other Primary Automotive Suppliers. This comprehensive definition within these three segments encompasses all industries which contribute products and services in automotive production.

With the transition to EV production, the automotive manufacturing sector is undergoing a significant transformation leading to substantial changes in its supply chain. At the core of this shift is the incorporation of battery manufacturing within the supply chain. The production of EV batteries is a multistage process that involves inputs from numerous industries and sectors. EV battery production spans from the procurement of raw materials to the assembly of battery cells into modules and packs. The involvement of multiple industries and sectors in the production of EV batteries is expected to broaden the definition and scope of the automotive supply chain. This expansion adds activities that have previously been considered "non-traditional" in automotive production. Below are the key stages of EV battery production:

Mining & Exploration

EV battery production begins with mining and exploration. Exploration begins with extensive geological surveys to locate viable deposits of these materials. Once potential mining sites are identified, further detailed analysis is conducted to assess the feasibility of extraction. Following exploration, mining activities take place where key battery raw materials such as lithium, cobalt, nickel, and manganese are extracted from the earth[19]. Mining activities involve both traditional open-pit and underground methods, and more recently, efforts to extract lithium from brine pools through a method known as "lithium brine extraction" have gained traction[20]. The mining stage is labour and capital intensive, requiring significant investment in equipment and workforce. As the demand for EVs continues to rise, the pressure on mining operations to increase output over the upcoming decades is becoming a significant challenge for the industry. It's important to note that the exploration and establishment of mining operations is not an overnight process. It often requires several years, sometimes a decade or more, to move from initial geological surveys to a fully operational mine.

Materials Filtering & Processing

The raw materials of a battery undergo a refining process to attain the purity levels required for battery usage. Lithium, for example, is often processed into lithium carbonate or lithium hydroxide before it can be used in battery applications. Cobalt and nickel also undergo refining to purify them to the specifications needed for battery chemistries. The refining process involves a series of chemical treatments, including leaching, precipitation, and electrolysis. These procedures are crucial for performance, as impurities can significantly affect battery life, capacity, and safety[21].

Battery Materials Manufacturing

Following the material refining stage, both cathode active material (CAM) and anode active material (AAM) are manufactured. CAM is produced from a mixture of lithium and other metals like nickel, manganese, and cobalt, while the anode active material (AAM) typically consists of graphite applied to copper foil[22]. The CAM process is preceded by the PCAM process which involves a series of chemical reactions and heat treatments including mixing, coating and drying to achieve the necessary crystalline structure for the material.

Battery Cell Manufacturing

Battery cells are the basic units of an EV battery, where the electrochemical reactions that store and release electricity occur. Assembling a cell involves stacking the anode, cathode, and

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[19] Rocky Mountain Institute (2023). *The EV Battery Supply Chain Explained.*
[20] McKinsey & Company (2022). *Lithium mining: How new production technologies could fuel the global EV revolution.*
[21] Saltworks Technologies (2023). *Lithium Extraction and Refining.*
[22] US Department of Energy (2023). *How Lithium-ion Batteries Work.*

separator— a porous membrane that prevents physical contact between the anode and cathode while allowing ionic flow[23]. These components are enclosed in a casing with the electrolyte. The cell manufacturing process is an intricate process that requires a cleanroom environment to prevent contamination. Any impurities can lead to reduced battery performance or safety issues.

Battery Module Manufacturing

Modules represent a functional unit within the battery pack. The assembly of battery modules is an intermediate step which involves grouping individual cells in series or in parallel to form modules. Module may include necessary electronics or systems to manage the cell environment such as sensors and voltage regulators[24].

Battery Pack Assembly

The pack assembly is the final stage in the battery manufacturing process. This process involves integrating the assembled modules into a unit within a battery pack enclosure. A battery pack also includes a cooling system to regulate temperatures, along with Battery Management System (BMS), which monitors and manages the battery's performance and operation.

Following the stages of battery production, a battery pack is integrated into a vehicle during vehicle assembly. In this phase, the EV's various components, including the electric motor, the power management unit, and other electrical systems, are assembled.

In the EV production supply chain, vehicle parts manufacturing remains at the core of the supply chain besides EV battery production. This includes the production of electric motors, vehicle electronics, inverters, converters, and other components that are distinct from those used in traditional ICEVs. For HEVs and PHEVs, ICEs are key components of their powertrains. Consequently, the production of combustion engines is anticipated to continue playing a crucial role in the automotive manufacturing supply chain as long as HEVs and PHEVs remain in production.

Appendix B presents a schematic of the automotive and battery manufacturing supply chains.

Methodology

An EV forecast model was developed to analyze and forecast the economic and labour market impacts of Canada's shift to EV and battery production. Using a two-step methodology and integrating a variety of analytical tools and data sources, the output and purchasing patterns of key industries in automotive and battery manufacturing are first calculated. The broader impacts

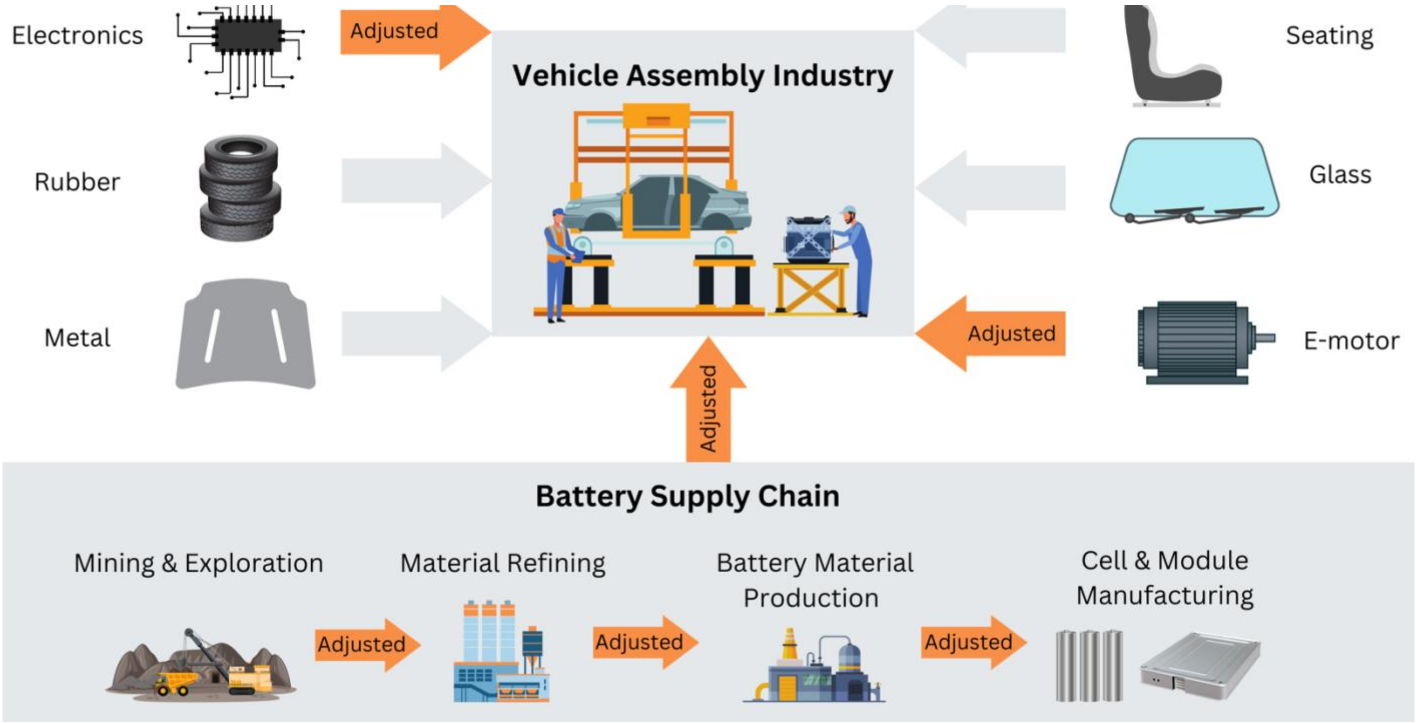
[23] Argonne National Laboratory (ANL) (2022). Battery Performance and Cost Modeling for Electric- Drive Vehicles (BatPaC).
[24] Samsung SDI (n.d.). The Composition of EV Batteries: Cells? Modules? Packs?

across the economy, presented using two main economic indicators: the impact on output and the impact employment, are measured using the IMPLAN Economic Software[25]. These impacts are quantified and presented in five-year intervals from 2025 to 2040. This methodology is summarized in the section below, and is detailed in Appendix C.

Estimating Industry Output and Purchasing Patterns

Canadian Input-Output (I-O) Tables, developed by Statistics Canada, are key tools for economic analysis, offering a detailed view of economic transactions and interconnectivity across various sectors and industries[26]. Organized into a multi-level structure, the most detailed - Level D I-O table, in particular, provides the most detailed insights with data on 236 industries and about 500 commodities, allowing for precise analysis of economic interactions[26]. To examine the shift from ICEV to EV production, the 2019 I-O Level D table is used to derive a cost structure of an average vehicle made in Canada. By dividing the total output and purchases of the vehicle assembly industry from each of the 236 industries (also known as the purchasing pattern) by the total number of vehicles produced, the average production cost and cost structure of a Canadian produced vehicle is obtained, primarily reflecting the costs associated with ICEVs[27].

Figure 3. Adjusted purchases and supply chain linkages within the automotive and battery manufacturing industries



[25] For more information on the IMPLAN modeling process, visit IMPLAN.com.
[26] Statistics Canada (2021). *Supply, Use and Input-Output Tables*.
[27] The majority of vehicles produced in Canada in 2019 were ICEVs (Marklines Automotive Industry Production Data).

To adapt these cost structures for HEVs, PHEVs, and BEVs, adjustments were made to reflect the unique manufacturing requirements and component costs of these vehicles. This included additions such as electric motors and battery packs of varying capacities (accounting for different vehicles sizes such as small, compact, SUV, and large vehicles), alongside other EV-specific components like inverters, converters, and high-voltage wires. The adjustments also took into account the lower ICEV-specific content in both HEVs and PHEVs, and their absence in BEVs. Similarly, the model extends to heavy-duty vehicle manufacturing, adjusting for hybrid and battery-powered heavy-duty buses and trucks, and including components like larger batteries. The model also accounts for the fluctuating costs of EV components, specifically the declining price of the battery's kWh.

Along with assumptions on vehicle production volumes, sizes and powertrain type mix, this approach allowed for an estimation of the projected output and purchasing pattern of the vehicle assembly industry covering the period from 2025 to 2040 (as shown in Figure 4). The vehicle production forecasts were derived from various sources and databases, and were extended to 2040 using a curve-fitting method for data extrapolation.

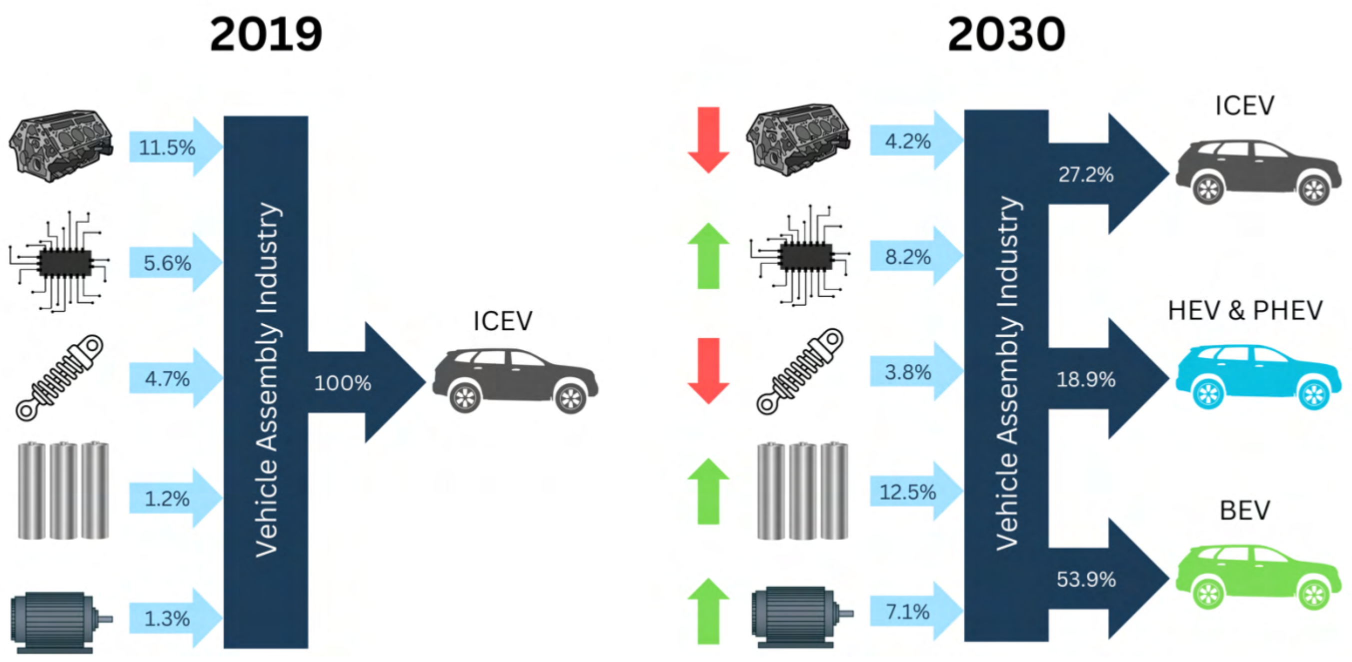
Adjustments were made to industries throughout the automotive and battery manufacturing supply chains to reflect changes in their purchasing patterns, and to estimate the total output of these industries. These changes included the battery cell and module manufacturing industry, and accounted for the different battery sizes and chemical compositions. Changes were also made to the cathode and anode manufacturing industry, the material filtering and refining industry, and mining sector.

Measuring Broader Economic Impacts

The second phase involves estimating the direct, indirect, and induced impacts as a result of changes in industry output and purchasing patterns. At this stage, the analysis calculates broader estimates of impacts on industry output and employment across the entire economy, with detail set out for 55 selected industries. The estimated outputs and purchasing patterns from the earlier stage of this model, along with other indicators are used as an input to measure the broader economic impacts. These inputs include the output and purchasing pattern of automotive assembly based on the projected vehicle production volumes of ICEVs and EVs, the adjusted export levels of ICEs, the production volumes of the newly announced for battery plants, and the production levels from domestic battery material manufacturing, battery material processing and filtering, and mining.

Each direct impact prompts a series of "indirect impacts" across the economy as the pattern of purchases and sales changes according to the structure of the economy set out in the IO tables. A final round of "induced impacts" are included as the I-O model tracks the changes in household income and the associated change in expenditures. Finally, the model totals the direct, indirect and induced output and employment impacts across in each industry.

Figure 4. Actual (2019) vs. projected (2030) purchasing pattern of the vehicle assembly industry



Vehicle & Battery Manufacturing Scenarios

Developing scenarios to demonstrate the economic and labour market impacts of the shift from ICEV to EV production is a critical part of this study. For this study, three detailed scenarios were designed, each encompassing a set of assumptions on vehicle production levels, the rate of transition to EV production, battery manufacturing investment and production, as well as the level of activity in the supply chain industries of automotive and battery manufacturing. These scenarios allow for the evaluation of a range of potential outcomes and uncertainties associated with this transition. The choice of multiple scenarios rather than a single scenario also enables a more comprehensive understanding and exploration of the potential implications of different levels of production and investment on the economic output and employment of various industries and sectors related to automotive and battery manufacturing.

It is also essential that these scenarios and assumptions are both realistic and accurate to measure the impact of the transition to EV production. For this reason, all three scenarios draw on data from multiple sources including historic automotive production levels, vehicle production forecasts, battery parts and material manufacturing investment announcements, as well as existing and planned mining development and exploration projects. This approach ensures that the scenarios are well-informed, comprehensive and based on a broad range of inputs.

To demonstrate the potential outcomes and contributions of vehicle and battery production, it was important to simulate a scenario where Canada's automotive manufacturing sector is capable of fully transitioning to the production of BEVs by 2040, while growing its North American vehicle production share relative to 2022 levels. In this scenario, Canada is also successful in developing and growing its battery production capabilities, which includes supplying battery components, materials and minerals domestically. In a second scenario, Canada's automotive manufacturing sector gradually transitions to the production of EVs as a result of a wide variety of risks and uncertainties related to consumer demand, supply chains, infrastructure, and investment. By 2040, the industry is producing a mix of ICEVs, hybrids, and BEVs. Canada's North American vehicle production remains below 2022 levels and while some battery plants come online during this period, domestic and North American demand remains low leading to lower levels of domestic production of battery and battery materials. A third scenario combines the first two scenarios. In this scenario, vehicle production in Canada fully transitions to BEV production however, the country's production share remains below 2022 levels. While Canada is successful in ramping up domestic battery production, the industry remains partially dependant on imports to source battery materials and minerals.

In developing the three scenarios, the following assumptions were made. These assumptions are summarized in Figure 5 and Table 1, and are detailed in Appendices D and E:

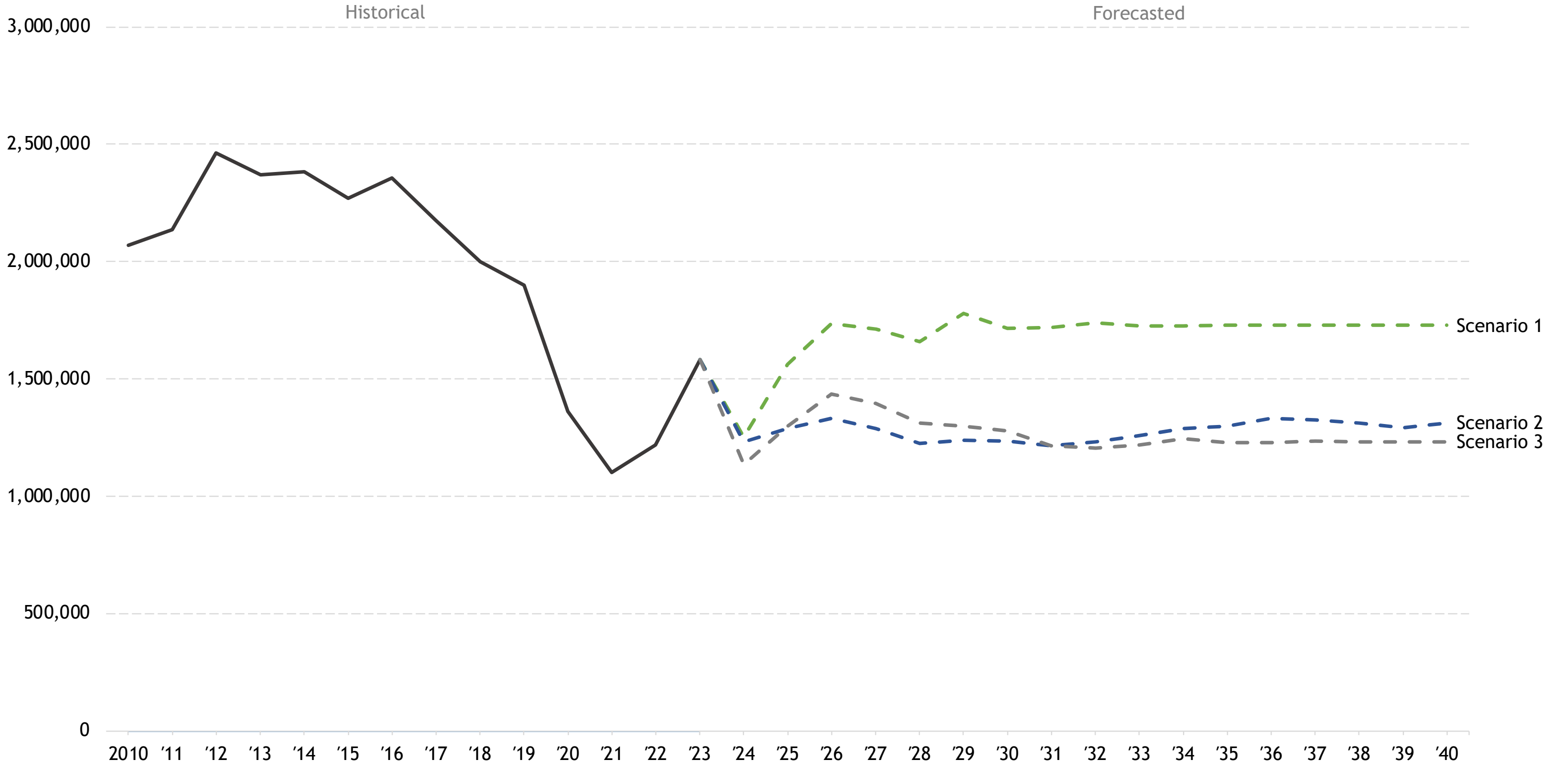
Scenario 1

In this scenario, it is assumed that Canada's vehicle manufacturing industry completely transitions to the production of BEVs over the forecast period. Concurrently, Canada's North American vehicle production share increases from approximately 8.3% in 2022 (producing 1.25 million vehicles) to close to 11.0% by 2040 (producing over 1.7 million vehicles). It is also assumed that four battery plants become operational during this period and operate at 75% capacity producing close to 152 GWh equivalent (eq.) of EV batteries. Within its developing battery manufacturing supply chain, Canada's battery material manufacturing, material refining and filtering, as well as mining industries are capable of supplying 100% of domestic demand of battery materials and minerals to manufacture batteries.

Scenario 2

Canada's vehicle manufacturing gradually transitions to the production of EVs and by 2040, is producing a mix of ICEVs, HEVs, PHEVs and BEVs. Canada's North American vehicle production share drops to 7.5% as the industry produces around 1.3 million vehicles in 2040. Only three battery manufacturing plants come online during the period of 2025 - 2040 which operate at an average of 30% capacity and produce close to 50 GWh. Battery material (cathode and anode materials), as well as battery minerals are mostly imported to satisfy domestic demand for battery production. Only 10% of the battery materials and minerals are domestically supplied from projects that become operational between 2025 and 2040.

Figure 5. Historical (2010 - 2023) and projected (2024 - 2040) vehicle assembly volumes in Canada across three production scenarios



Sources: International Organization of Motor Vehicle Manufacturers (OICA), Marklines, & Author's Calculations

Scenario 3

In scenario 3, Canada produces close to 1.25 million vehicles in 2040, all of which are BEVs. Similar to scenario 1, battery production is ramped up to reach 152 GWh eq. of EV batteries however, only 55% of the domestic demand of battery cathode and anode materials, as well as battery minerals are supplied domestically.

In constructing the three scenarios, automotive production forecast data was purchased from both GlobalData Automotive Production Forecast and S&P Global Automotive Production Forecast. Both datasets offered a detailed breakdown of projected vehicle production by vehicle powertrain type and size in Canada and across North America over the upcoming 10 to 15 years.

To cover the period of this analysis, both datasets were extended till 2040. Both datasets were also used to inform the potential rates of transition in production.

Table 1. Assumptions for battery manufacturing in Canada by 2040 across the three scenarios

	Scenario 1	Scenario 2	Scenario 3
Number of Battery Plants (by 2040)	4	3	4
Total Operational Battery Production Capacity (by 2040)	151.5 GWh	49.5 GWh	151.5 GWh
Cathode & Anode Manufacturing[28]	100%	10%	55%
Material Filtering[28]	100%	10%	55%
Mining[28, 29]	100%	10%	55%

As for existing and potential battery manufacturing capabilities, data was collected on all announced and planned battery component and material production projects across Canada. This information and data were used to develop the assumptions in the three scenarios of this study. Industry experts were consulted on the range and feasibility of the assumptions of each of the three scenarios.

Results & Findings

The automotive sector's transition to EV production under the three electrification and battery manufacturing scenarios presented above suggest a multifaceted economic impact. All results in the sections below are presented relative to 2022 levels of output and employment. In Scenario 1, characterized by an aggressive shift towards EV manufacturing and growing production volumes, notable economic expansion is observed, with the total change in output across the economy projected to grow from $12.5 billion in 2025 to over $50.0 billion by 2040. Accompanying this output growth is an optimistic job market forecast, suggesting an overall employment increase of almost 100,000 jobs, highlighting the substantial job creation potential of aggressive investment and production of EVs, batteries, and battery components and materials.

In the second scenario, which adopts a gradual approach to EV production and lower vehicle production levels, the economic impact is significantly lower. Economic output as a result of the shift in this scenario is projected to grow by around $2.4 billion, despite some notable losses in output in 2025 and 2030 ranging between $8.0 billion and $11.6 billion. Employment is also expected to follow the same trend. Employment projections indicate an overall increase of around

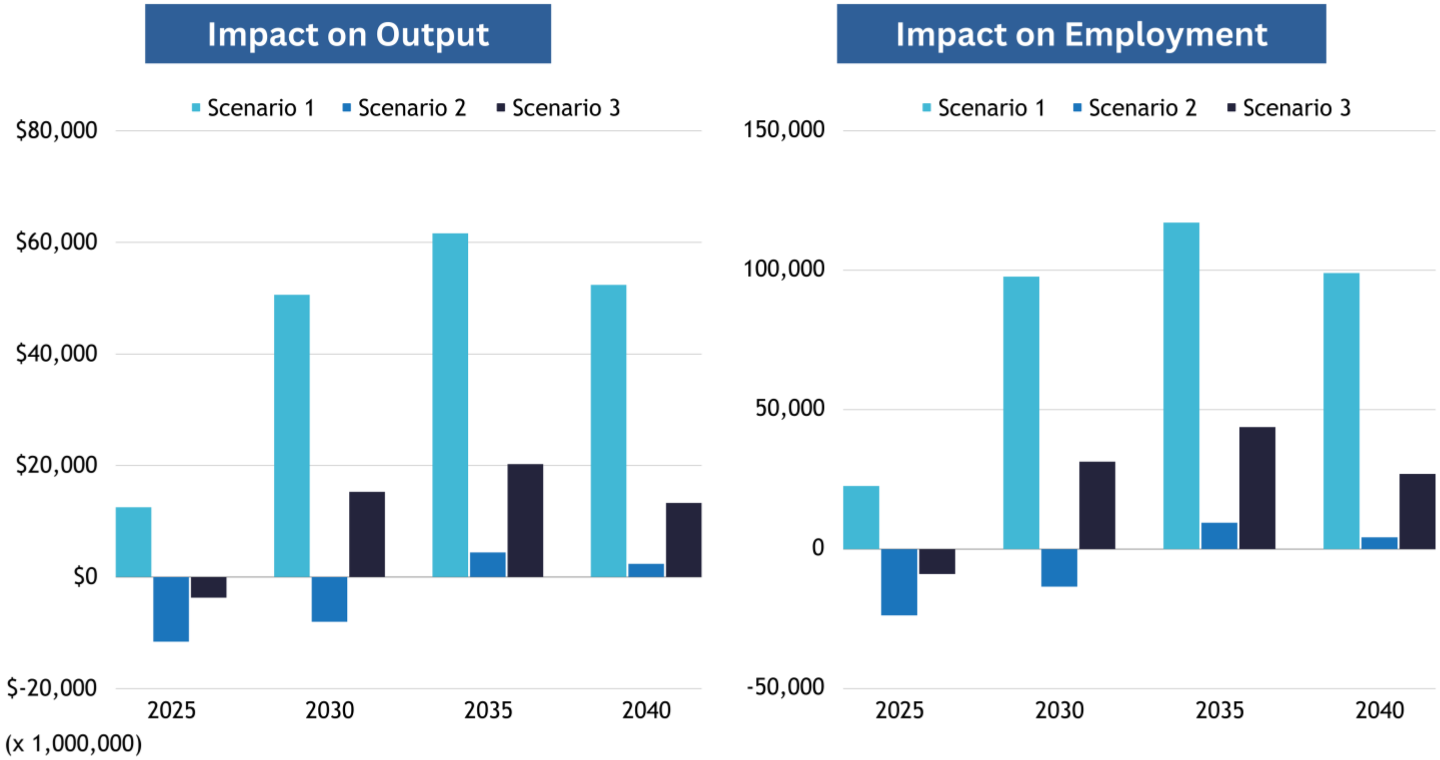
[28] Of battery material upstream domestic demand.
[29] Except Cobalt.

4,250 jobs by 2040, with job losses across the economy of 23,800 in 2025, and 14,500 in 2030. The economic contribution of scenario 3 falls between scenarios 1 and 2. In scenario 3, the projected total change in output across the economy is set to reach $13.3 billion by 2040. Around 27,000 jobs are expected to be added across the economy by the end of the forecast period.

It is important to note that in all three scenarios, output and employment peaks around 2035 before moderately declining by 2040. For example, output in scenario 1 is expected to peak at $61.6 billion in 2035 before declining to $52.4 billion in 2040. Similarly, employment peaks in this scenario at 117,000 jobs created in 2035 before settling at 99,000 in 2040. A similar trend in output and employment change can be observed in scenarios 2 and 3. This peak is a result of a combination of factors including all battery manufacturing plants reaching peak production capacity around 2035, as well as a higher battery component and material prices in 2035 compared to 2040. Prices are expected to decline with higher economies of scale and productivity in battery production. This leads to a decline in both the output and employment of battery manufacturing, and consequently, vehicle assembly.

In the section below, the economic and job impact results of the three scenarios are described. The results are further detailed in Appendix F. A total of 18 industries within segments of automotive and battery manufacturing are highlighted. The impact on output and employment within the rest of the automotive manufacturing supply chain (as previously defined by FOCAL), and the rest of the economy is also presented.

Figure 6. Overall impact on output and employment in each of the three EV transition scenarios

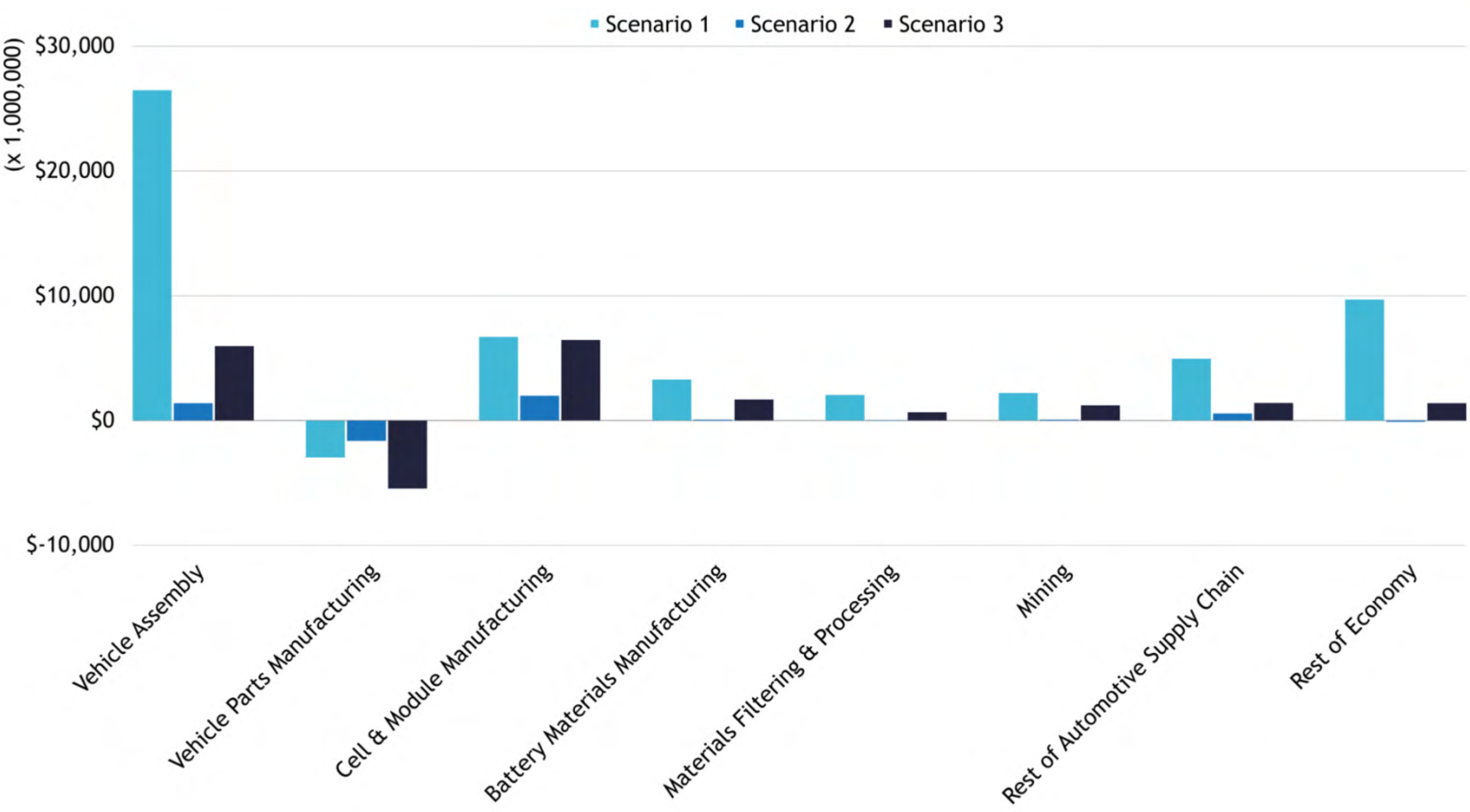


Impact on Output

Scenario 1, which simulates the impact of an aggressive shift towards BEV production, suggests significant changes within Canada's automotive industry and its supply chain. The data indicate that, based on the projected vehicle production volumes and powertrain type mix, the output in the light-duty motor vehicle manufacturing industry will increase around $22.0 billion by 2030 and $26.0 billion by 2040. The output of heavy-duty truck manufacturing is also projected to rise by around $750 million by the end of the forecast period. This aligns with the scenario's assumption of an increasing North American vehicle production share, and investment in EV manufacturing capabilities.

In contrast, the output for gasoline engine and engine parts manufacturing is projected to decline by approximately $4.5 billion by 2040. Similarly, the output of transmission and powertrain parts manufacturing is expected to decrease during this period. This is reflective of the scenario's anticipated reduction in ICEV-specific parts and components production and exports. Overall, as a result of the shift to BEV production in scenario 1, the output of the vehicle parts manufacturing industry will decline by around $3.0 billion.

Figure 7. Impact on output by 2040 in each of the three EV transition scenarios



The increase in battery manufacturing output can be directly linked to the investment announcements related to battery cell and module manufacturing facilities that are taken into account in scenario 1. Output of battery manufacturing is projected to increase over the upcoming years, and is expected to peak around 2035, as new production adds $9.0 billion in activity in the industry. Output decreases slightly by 2040 as a result of the battery's declining kWh price.

Material processing industries, as well as mining industries, are forecasted to see an increase in output that aligns with the growing demand for EV components, adding $5.3 billion and $2.2 billion respectively by 2040.

Scenario 2, which models a more gradual shift towards EV production, indicates less pronounced changes by 2040 within Canada's automotive industry and its supply chain when compared to Scenario 1. In this scenario, however, output of multiple industries is expected to decline in 2025 and 2030 before slightly growing in 2035 and 2040.

The output of light-duty motor vehicle manufacturing is projected to increase slightly, by $1.2 billion by 2040, recovering from a decline of $6.2 billion in 2030. Modest growth is also expected in heavy-duty truck manufacturing, with an increase of about $220 million by 2040.

Declines in output are expected across most of the sub-industries of vehicle parts manufacturing over the duration of the forecast in scenario 2. A decline of $1.0 billion in the output of gasoline engine manufacturing is expected by 2040, which is less severe compared to scenario 1. This comes as a result of the vehicle production mix in 2040, which includes a majority of ICEVs, HEVs, and PHEVs, all which require ICEs and their components.

Battery manufacturing output is projected to grow at a slower pace compared to scenario 1, with an increase of around $2.0 billion by 2040. This reflects the scenario's more conservative assumptions about the scale of investment in production facilities, and the volume of production of batteries.

Material processing and mining industries, while still experiencing growth due to the demand for EV components, see slight increase in output by 2040.

Finally, output in the rest of the automotive manufacturing supply chain is only expected to increase by slightly over half a billion dollars by 2040.

Scenario 3 combines the accelerated transition to BEV production from scenario 1, with the vehicle production levels of scenario 2. In this scenario, the output of light-duty vehicle manufacturing is projected to grow by $5.2 billion by 2040, mainly driven by the higher average price of a BEV compared to other vehicle types. Similar to scenario 2, heavy-duty truck manufacturing sees a modest increase of $220 million by 2040.

The output of gasoline engine manufacturing is projected to decline by $4.5 billion by 2040. This reflects the diminishing reliance on ICEV-specific components which are sourced from this industry.

Battery manufacturing is projected to see a substantial increase in output over the duration of the forecast period. Output of the battery manufacturing is expected to grow by $8.8 billion by 2035, and $6.5 billion by 2040. This growth is fueled by the continued investments in battery manufacturing, and the scaling up of production in facilities.

Material processing and mining industries also see increases in output despite the lower production volumes compared to scenario 1. Output of material processing is projected to increase by $2.4 billion, while mining benefits from a rise of $1.2 billion by 2040.

Impact on Employment

Employment changes reflect the shifts in output. In scenario 1, employment in the automobile and light-duty motor vehicle manufacturing is anticipated to increase by around 18,000 jobs by 2040. During the same period, heavy-duty vehicle manufacturing is expected to add 1,660 jobs.

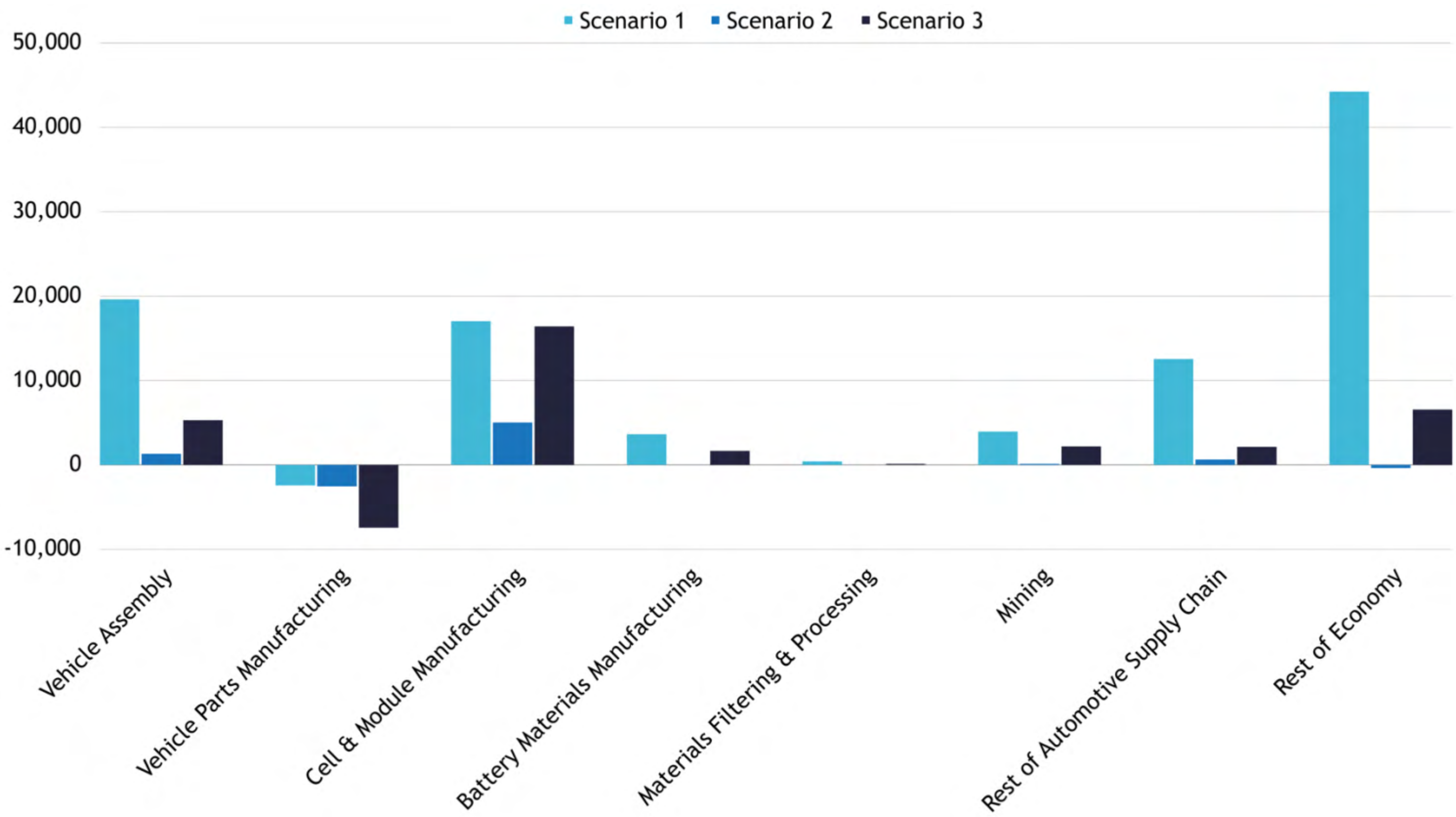
Overall, employment in vehicle parts manufacturing is projected to decline by approximately 2,400 jobs by the end of the forecast period of scenario 1. While employment increases in most sub-industries within vehicle parts manufacturing, the overall decline in employment is mostly led by declines in gasoline engine manufacturing (loss of 5,200 jobs), and transmission and powertrain parts manufacturing (loss of 800 jobs).

Significant job gains are expected with the battery manufacturing supply chain. Cells and modules manufacturing is expected to add 17,000 jobs as a result of the newly announced battery manufacturing plants. This increase however is a slight decline from 2035 (23,250 jobs added) which comes as a result of the increase in productivity, as well as streamlining manufacturing processes with the production achieving economies of scale. Materials processing and mining industries are expected to add 4,000 jobs each.

Besides the job gains in both vehicle assembly and battery manufacturing, employment growth of 57,000 jobs is projected within the rest of the automotive manufacturing supply chain, as well as the rest of the economy.

In scenario 2, employment changes exhibit similar patterns to output changes. The light-duty vehicle manufacturing industry is anticipated to only add 800 jobs by 2040. Heavy-duty truck manufacturing employment only increases by 500 jobs by 2040.

Figure 8. Impact on employment by 2040 in each of the three EV transition scenarios



Overall, employment in vehicle parts manufacturing is projected to decrease by 2,550 jobs by 2040. Close to 1,200 jobs are lost in gasoline engine manufacturing, significantly less than the job losses in the same industry in scenario 1.

The battery manufacturing supply chain is expected to add 5,200 jobs. This growth, however, is mostly driven by jobs created within cell and module manufacturing operations, as the rest of the battery manufacturing supply chain industries are expected to supply only 10% of the upstream domestic demand of battery components, materials and minerals.

In line with the output changes in scenario 3, employment across automotive manufacturing exhibits both growth and decline. Light-duty vehicle manufacturing and heavy-duty truck manufacturing are expected to add 3,650 jobs and 1,660 jobs respectively by 2040.
Job losses in the parts manufacturing industry in scenario 3 are significantly higher compared to scenarios 1 and 2. The diminishing contribution of the gasoline engine manufacturing industry throughout the transition period, along with the relatively lower vehicle production levels lead to a loss of almost 7,500 jobs in the parts manufacturing industry, which is three times higher than the losses in scenarios 1 and 2.

Significant job gains are expected in the battery manufacturing supply chain. This is mainly driven by the 16,500 jobs created in battery cell and module manufacturing. Around 4,000 jobs are added in the industries of both material processing and mining.

Discussion

The analysis of the transition to EV and battery production in Canada's automotive industry, as outlined in the results of this study, provides comprehensive insight into the various potential outcomes of this transition. The shift to EV production is expected to have a diverse and far-reaching impact across multiple industries, both within and beyond automotive manufacturing. In the analysis presented above, multiple observations on the overall economic impact, vehicle assembly, parts manufacturing, and battery manufacturing can be made from the results of the three scenarios.

Overall Economic Impact

The projected potential economic contribution demonstrated in scenrios 1 and 3 (both depicting an accelerated transition to EV production at different vehicle production levels) indicate that Canada has a lot at stake in its transition to EV production. A growth of over $52 billion in output and an addition of almost 100,000 jobs are projected by 2040 in scenario 1 (a result of growing vehicle production, an accelerated shift to EV production, and growing battery production capabilities). Similar observations can be established in scenario 3. Despite lower vehicle production volumes compared to scenario 1, the automotive manufacturing sector, and the whole economy is set to benefit from the accelerated shift to EV production, and the investment in battery manufacturing, and battery components and materials production. The minor change in economic contribution as a result of a slower transition to EV production and low investment in battery manufacturing demonstrates the risk of missing this opportunity.

Vehicle Assembly

In 2022, the vehicle assembly industry (consisting of both light and heavy-duty vehicle manufacturing) had an output of $48.7 billion and employed around 37,300 workers (as shown in Figure 9). Output and employment of both light-duty vehicle and heavy-duty truck manufacturing consistently showed growth, though by varying degrees, across all scenarios by the end of the forecast period. In scenario 1, output and employment growth in light-duty vehicle manufacturing is driven by two main factors: growing production levels, and the shift to BEV production, which costs more to produce compared to ICEVs. Output and employment growth in heavy-duty truck manufacturing is driven by similar influencing factors. In scenario 3, this growth is driven by the latter only, as lower vehicle production levels with a rapid transition to BEVs is assumed. The slight growth in output and employment in scenario 2 is a result of the higher average vehicle production cost as a mix of ICEVs, hybrids and BEVs are produced. Therefore, the actual potential of the shift to BEV production is demonstrated when the results of scenarios 2 and 3 are compared. Given that both scenarios (2 & 3) assume comparable vehicle production levels, the economic contribution of producing EVs and BEVs is projected to be higher than that of producing ICEVs only.

As Canada's vehicle assembly industry shifts to producing hybrids and BEVs, the economic contribution of the vehicle assembly industry is expected to grow as a result of the higher value of these vehicle types. If Canada is successful in winning additional production mandates, the economic contribution of vehicle assembly is likely to see a further significant increase.

Gasoline Engine Manufacturing

Gasoline engine manufacturing is expected to be the most affected industry within vehicle parts manufacturing (and across the whole economy) as a result of the shift to producing EVs, and more specifically BEVs. In both scenarios 1 and 3, output and employment in gasoline engine manufacturing is expected to significantly decline as a result of phasing out ICEVs and shifting towards BEV production. The output of Canada's gasoline engine manufacturing industry is anticipated to be influenced by two key factors: the diminishing demand in domestic markets, and the potential reduction in exports. As Canada produces less ICEVs, domestic sales of combustion engine parts and components are expected to decline. As Canada's primary export market of ICE parts and components (i.e., US) shifts towards BEV production, exports of gasoline engines and engine parts are likely to contract, further impacting the industry. As a reduction in domestic sales and exports of ICEV components and parts is simulated scenarios 1 and 3, the output and employment of gasoline engine manufacturing is expected to decline by over 90% by 2040 as demonstrated in Table 2. The remaining output and employment of gasoline engine manufacturing is anticipated to be a result of purchases from other industries including automotive maintenance, aftermarket, and agricultural equipment.

Table 2. Change in gasoline engine manufacturing employment relative to 2022 levels

	2025	2030	2035	2040
Scenario 1	-9.80%	-49.57%	-86.90%	-92.41%
Scenario 2	-2.47%	-10.11%	-16.89%	-20.92%
Scenario 3	-10.49%	-50.17%	-87.03%	-92.44%

Battery Manufacturing

As a result of the newly announced investments in battery cell and module manufacturing across Canada, all of which are accounted for in the three scenarios of this analysis, the output and employment of the battery manufacturing industry is expected to significantly grow. The sub-industry of battery manufacturing falls under the industry of other electrical equipment and component manufacturing (NAICS 3359). For reference, in 2022, the other electrical equipment and component manufacturing industry had an output of around $5.5 billion and employed around 14,800 people [30]. With the newly announced battery manufacturing operations, the output of this industry is expected to grow by anywhere between $2.7 billion (scenario 2) and $9.1 billion (scenario 1) by 2035, and $1.9 billion (scenario 2) and $6.7 billion (scenario 1) by 2040. Employment is expected to grow by anywhere between 6,900 (scenario 2) and 23,200 (scenario 1) workers by 2035, and 5,000 (scenario 2) and 17,000 (scenario 1) by 2040.

The substantial growth in output and employment demonstrates the significant potential of the newly announced investment in battery manufacturing. Operating at anywhere between 30% and 75% of the announced capacity of these plants, the industry could experience an expansion in its economic contribution and labour market.

Battery Materials Manufacturing, Filtering and Mining

Investment in expanding the domestic capabilities of the battery manufacturing supply chain is set to benefit multiple industries. Investment in CAM, PCAM, AMM manufacturing, as well as material filtering and processing capabilities is set to significantly grow the output and employment of the basic chemical manufacturing, and other material and minerals manufacturing industries. As demonstrated in scenario 1, developing domestic capabilities to fully supply Canada's upstream domestic demand of battery materials can generate over $5.3 billion and add over 4,000 jobs in these two industries by 2040. Negligible change in output and employment is observed in scenario 2 as a result of only supplying 10% of Canada's upstream domestic demand.

Similar observations can be made in the mining sector. Investing to ramp up Canada's mining exploration, development, and most importantly production capabilities can generate as much as $2.2 billion in output, and create another 4,000 jobs.

Overall, despite the concerns articulated in the beginning of the report on the loss of the role and economic contribution of the gasoline engine manufacturing industry as a result of the accelerated transition to EV production, the results of scenarios 1 and 3 indicate that any losses in the gasoline engine manufacturing industry are likely to be offset by significant gains in other

[30] Battery manufacturing (NAICS 335910) falls under other electrical equipment and component manufacturing (NAICS 3359). Battery manufacturing had an output of $240 million and employed 800 people in 2022.

sectors and industries, particularly in battery and material manufacturing, as well as mining. From a broader economic perspective, this shift represents a reallocation of economic activity within the automotive sector, moving from traditional ICEV-related industries to emerging EV-related ones. However, this fundamental shift in the supply chain structure of the automotive manufacturing supply chain represents a challenge for the sector, especially for businesses and operations with the most exposure to the risk of declining sales as a result of the shrinking demand for ICEV-specific components. As the role of these businesses becomes obsolete over the years of transition, thousands of workers are expected to be at high risk of job losses. It is therefore critical for the industry and government to intervene and assist both businesses and workers in transitioning and keeping up with the changing landscape of automotive manufacturing. For businesses, this may involve support for retooling and modernizing their manufacturing operations to produce EV components instead of ICEV parts. This support may be in the form of financial incentives, tax breaks, grants, or subsidies to facilitate the acquisition of new machinery and technology necessary for producing EV components and parts.

As it relates to workers, the focus may include retraining, upskilling, and assisting in transitioning across other occupations or sectors. Programs designed to equip workers with the skills required in the emerging EV sector may include technical training for EV and battery manufacturing, electric powertrain maintenance, and other specialized skills unique to EVs. In transitioning workers to other occupations or sectors, tools such as FOCAL's Skills Transferability Matrices (STMs) can play a critical role in determining the best fit occupations, industries and sectors for workers. Furthermore, job placement assistance is a key component of these efforts, ensuring that workers can smoothly transition to new roles within the automotive industry or in other sectors.

The analysis in this report also indicates significant potential for economic and job growth in industries and activities within the battery manufacturing supply chain. This suggests that there may be a need for a broader strategic plan at the national or provincial levels to effectively manage this transition, and to incentivize investment and growth beyond vehicle and battery cell and module manufacturing. These coordinated efforts may involve ensuring the availability of necessary raw materials for domestic battery production operations, steps which include channeling investment and incentives to projects within battery materials manufacturing, materials filtering and processing, and mining.

Figure 9. Change in output and employment by 2040 relative to 2022 base levels

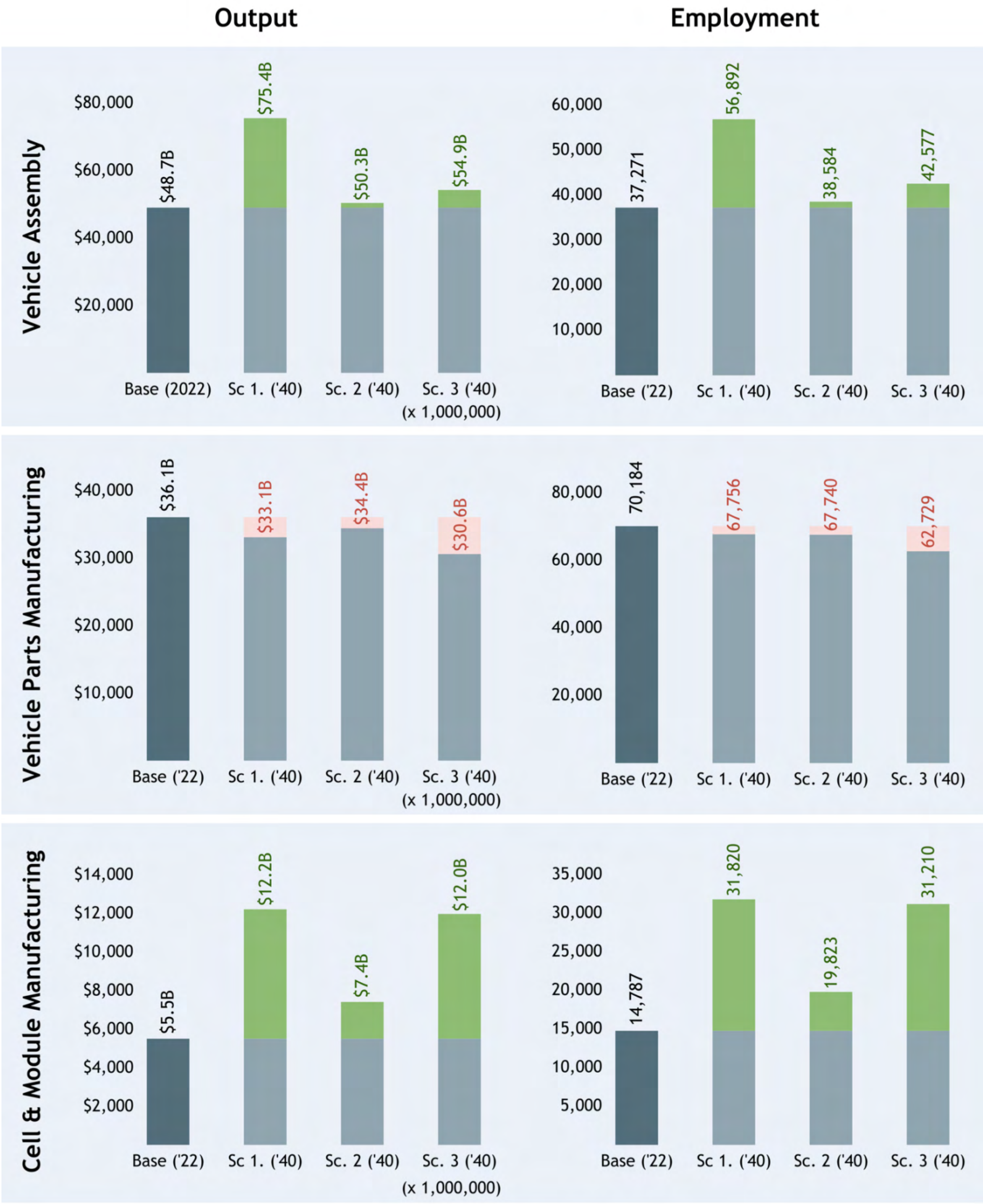
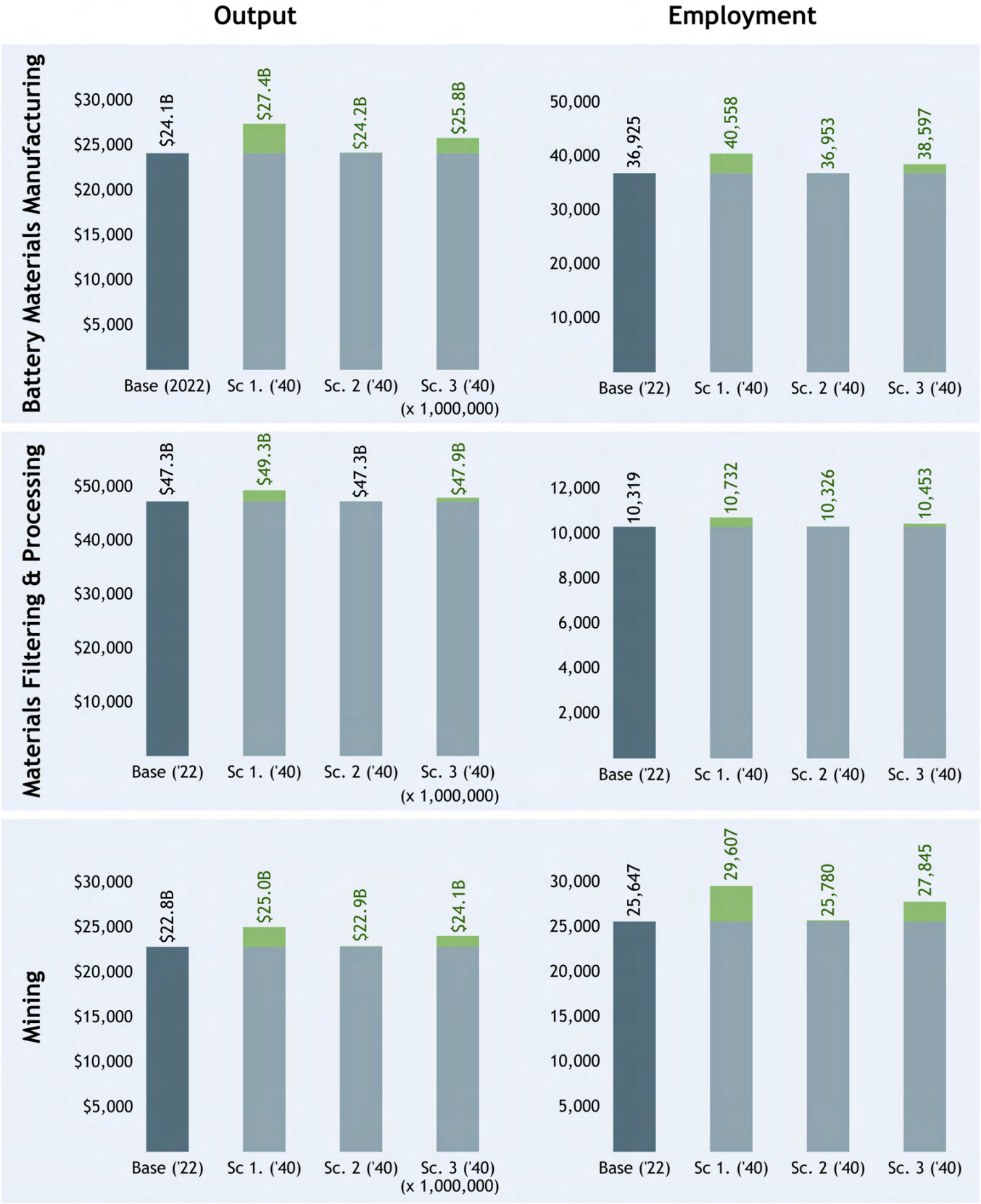


Figure 10. Change in output and employment by 2040 relative to 2022 base levels (cont'd)



Risks & Barriers

As indicated earlier in this report, the transition to EV production in Canada's automotive manufacturing supply chain is expected to be accompanied by a set of technological, supply chain, market-related and policy challenges and risks, among others. Acknowledging and addressing these challenges is crucial, as they pose significant barriers to the successful transition to EVs, both in production and adoption. Navigating these challenges requires strategic and coordinated efforts from industry and government to navigate the complexities and ensure a smooth transition.

Multiple technological and infrastructure-related constraints and shortcomings of EVs may influence the transition, impacting vehicle adoption, and consequently production. One significant issue is range anxiety, where drivers are concerned about the limited distance an EV can cover on a single charge, especially when compared to an ICEV. This issue is exacerbated in cold weather, which leads to a reduced efficiency in EV batteries, causing a decrease in both range and performance[31]. The transition may be also hindered by infrastructure limitations such as grid capacity constraints and insufficient charging stations, especially in rural and remote locations. The Canadian context, with its vast geography and extreme weather conditions in the winter, intensifies these concerns, making it imperative for EV technology and infrastructure to adapt and evolve to meet these unique challenges.

Additionally, the lifespan and degradation of EV batteries are pressing concerns. Over time, EV batteries lose capacity and efficiency, raising questions about the longevity and reliability of the vehicle. Charging speed, despite recent advancements, is also a constraint. The time it takes to fully charge an EV battery, especially a BEV, is still significantly longer than the speed of refueling.

Despite the growing awareness and interest in EVs, there remains a level of consumer skepticism concerning their performance, reliability, and convenience, influencing overall consumer preferences and market trends[32]. Additionally, the market currently offers a relatively limited variety of EV models compared to ICEVs, a factor that can deter consumers with specific needs or preferences. Another significant barrier is the high initial purchase price of EVs, which tends to be more than that of comparable ICEVs. Furthermore, the cost of EV technology, particularly the battery systems, remains high, which acts as a barrier to their widespread adoption, especially when maintenance requirements are taken into consideration.

The transition to EVs may also be faced by production and supply chain-related challenges. The battery manufacturing industry faces critical risks in raw material availability, especially that of lithium and cobalt[33, 34]. Commodity price fluctuations, as well as geopolitical tensions can lead to

[31] Consumer Reports (2024). *How Much Do Cold Temperatures Affect an Electric Vehicle's Driving Range?*
[32] Canadian Automobile Association (CAA) (2023). *The Voice of the Canadian Electric Vehicle Driver*.
[33] CNBC (2023). *A worldwide lithium shortage could come as soon as 2025*.
[34] Reuters (2021). Shortages flagged for EV materials lithium and cobalt.

supply disruptions, increasing production costs and causing delays. Humanitarian concerns can also weigh in, particularly related to mining in regions like the Democratic Republic of Congo (DRC), known for cobalt mining under often unethical labour conditions[35].

Finally, policy and regulatory uncertainties may impact EV production and adoption. This includes cross-border trade issues, inconsistent government support, and domestic and regional political agendas which may not align with the EV transition efforts.

The production and adoption-related challenges and risks outlined above may individually or collectively influence EV uptake, and therefore shape the trajectory of the transition in Canada's automotive and battery manufacturing supply chains.

Concluding Remarks

From the analysis presented in this report, it is evident that this shift to EVs can bring both challenges and opportunities for the Canadian automotive manufacturing sector. As the sector moves away from ICEV production, there is a need for significant technological adaptation, workforce reskilling and transitioning, and supply chain realignment. However, this transition also presents immense potential for economic growth, job creation, and environmental sustainability for Canada.

This report explored the various aspects of this shift, and in its scenarios accounted for the different potential outcomes of this transition. The results of this analysis demonstrated a significant output growth and job creation potential if Canada's manufacturing automotive sector is successful in expanding its vehicle and battery manufacturing capacities. The results also indicate that Canada's economy, particularly its automotive and battery manufacturing industries, have a lot at stake in this transition. The success of this transition is bound to multiple factors, including Canada winning new vehicle production mandates, ramping up domestic battery production capacity, and sourcing the required battery components and materials.

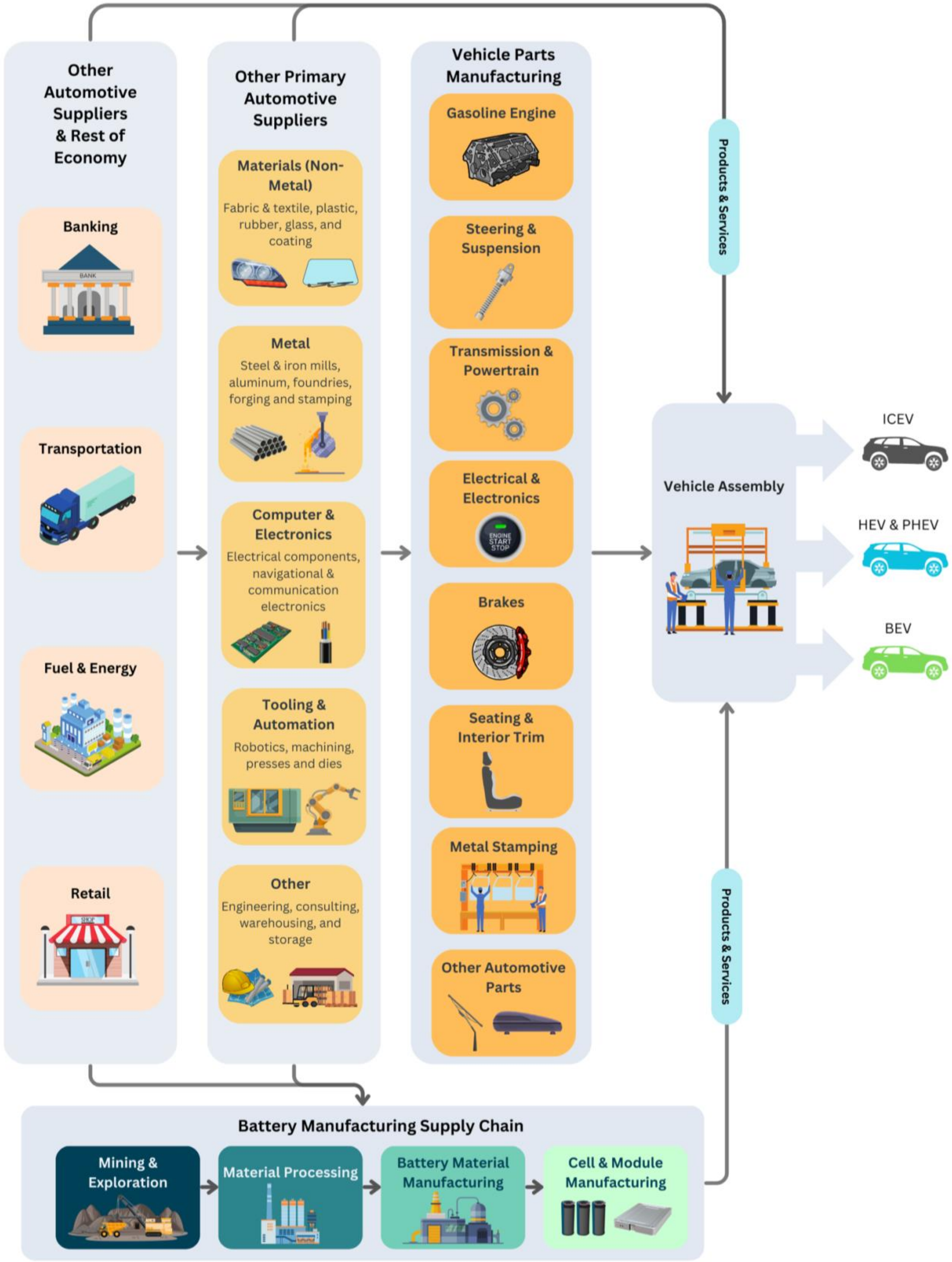
[35] Automotive News (2021). *EV supply chain scrutinized over human rights abuses, environment.*

Appendix A. Select EV & Battery Manufacturing Investment Projects & Announcements

Announcement	Details	Announced Capacity	Location	Production Planned / Commenced
General Motors CAMI Assembly Plant	Battery electric delivery van assembly	Up to 50,000 vehicles	Ingersoll, ON	2022
Ford Motor Company Oakville Assembly Plant	Electric vehicle and battery pack assembly	-	Oakville, ON	2025
Stellantis-LG Energy Solution Battery Plant (NextStar Energy)	Battery cell and module manufacturing	49.5 GWh	Windsor, ON	2024
Volkswagen PowerCo SE Battery Plant	Battery cell manufacturing	90 GWh	St. Thomas, ON	2027
Northvolt Battery Manufacturing	Battery cell manufacturing; Cathode components; Battery recycling	30 GWh	Montréal, QC	2026
Umicore EV Materials Plant	pCAM and CAM manufacturing	35 GWh eq.	Loyalist, ON	2025
Nouveau Monde Graphite Plant	Coated spherical purified graphite	42,600 tonnes per annum	QC	-
Baie-Comeau Battery Anode Material Plant	Battery anode material production	200,000 tonnes per annum	Baie-Comeau, QC	2026

Allkem - James Bay Lithium Project	Spodumene - high-grade lithium	321,000 tonnes per annum	QC	2024
Electra Battery Materials - Cobalt Refinery	Battery grade cobalt sulfate	6,500 tonnes per annum	Temiskaming Shores, ON	2023
Nouveau Monde Graphite - Matawinie Graphite Mine	High-purity graphite concentrate	100,000 tonnes per annum	Matawinie, QC	-
Northern Graphite Corporation - Bissett Creek Graphite Mine	Graphite flakes	40,000 tonnes per annum	ON	2022

Appendix B. Schematic of the Automotive & Battery Manufacturing Supply Chains



Appendix C. Detailed EV Impact Analysis Methodology

To forecast the economic and labour market impacts of transitioning to EV production and battery manufacturing in Canada, an EV forecast model was developed. This model employs a two-step methodology and utilizes various analytical tools. The first step involves estimating the output and purchasing patterns of a select number of key industries within the automotive and battery manufacturing and their supply chains. For this, a model was developed in Microsoft Excel which incorporates technical and economic data drawn from multiple sources. After estimating the output and purchasing patterns of these industries, the second step entails utilizing the IMPLAN Economic Software to assess the direct, indirect, and induced impacts of transitioning to EV production and battery manufacturing. This assessment spans over 230 industries in the Canadian economy. The results yield two key economic indicators, the impact on output and impact on employment. The changes in output and employment are quantified and presented in five-year intervals, covering the period from 2025 to 2040. In the sections below, the structure of the EV forecast model is detailed.

Overview of Canadian Input-Output Tables

Canadian Input-Output (I-O) Tables are an integral part of the country's economic analysis tools, developed and maintained by Statistics Canada. These tables provide a comprehensive overview of the economic transactions between different sectors and industries within the Canadian economy. They track how outputs from one industry become inputs for another, offering insights into the interconnected nature of industries, sectors, and the whole economy. I-O tables are organized into a multi-level structure, ranging from high-level aggregates to detailed sector-specific data (levels L, M, H, and D)[36]. This structure allows for various degrees of analysis, from broad overviews of economic relationships to in-depth sectoral studies.

The level D I-O table represents the most detailed tier in the four-level structure of Canada's I-O tables, offering granular data on economic transactions. It includes 236 industries and approximately 500 commodities, enabling analysts to examine the intricate economic interactions with a high degree of specificity.

Detailed Cost Structure Analysis using I-O Tables

In the context of the automotive manufacturing sector's shift from the production of ICEVs to EVs, the level D I-O table is a valuable resource. It allows for the analysis of how changes in the

[36] I-O tables are organized into a multi-level structure. Level L (Lowest Level of Aggregation) offers a broad macroeconomic overview with the economy aggregated into a few large sectors; Level M (Medium Level of Aggregation) provides a medium level of detail, breaking the economy into more sectors; Level H (High Level of Aggregation) offers a higher level of detail with an increased number of sectors; and Level D (Detailed Level of Aggregation) presents the most granular view, detailing the economy into hundreds of specific sectors for in-depth analysis.

production of the automotive sector influence related industries, such as parts manufacturing (especially ICE production), battery production, chemical manufacturing and mining.

In this study, the 2019 I-O level D table was utilized to derive a detailed cost structure breakdown of an average vehicle produced in Canada. By analyzing the I-O table, the input values or purchasing pattern of light-duty vehicle manufacturing (NAICS 336110) from each of the 236 industries in the I-O table was determined. These values were then divided by the total number of vehicles produced in Canada in 2019 to obtain the average production cost, as well as the average input values contributed by each of the 236 industries on a per vehicle basis. Given that the predominant type of vehicle manufactured by Canadian automakers in 2019 was the ICEV, the cost structure obtained primarily reflects that of a Canadian-produced ICEV.

Subsequently, to obtain the production costs and the cost structures of Canadian-produced HEVs, PHEVs, and BEVs, adjustments were made to these input values or purchasing pattern on a per vehicle basis. These adjustments took into account the different manufacturing requirements, and part and component costs specific to HEVs, PHEVs, and BEVs. This included considerations for battery packs, electric drivetrain components, and other unique parts not found in ICEVs. For example, electric motors, as well as battery packs at an average capacity of 1.5 kWh and 12.5 kWh respectively were added to HEVs and PHEVs. For BEVs, three cost structure variations were developed. One electric motor and a 44-kWh battery pack was added to a small-sized BEV. For both compact and midsize BEVs, two electric motors, along with a 77-kWh battery pack was added to the cost structure. Finally, for large BEV such as pickup trucks, two electric motors and a 109-kWh battery pack was added to the vehicle cost structure[37,38]. Other components were also added to these vehicles including inverters, converters, high-voltage wires and power control units where applicable. The adjustments also took into account the lower ICEV-specific content in both HEVs and PHEVs, and their absence in BEVs. For BEVs, any purchases of ICE-specific components such as pistons, mufflers, and fuel tanks were eliminated from the cost structure of the vehicle. Component cost and technical details on the vehicle were obtained from multiple sources including United States Department of Energy's Battery Performance and Cost Estimation (BatPaC) modeling tool[39], Munro's vehicle cost breakdown data[40], and UBS's Evidence Lab Electric Car Teardown[41].

It is important to note that the production costs and the cost structures of these vehicles, particularly the three variations of BEVs, vary significantly over time. The price per kWh of battery

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[37] The average battery capacity, electric motor power, and other vehicle specifications were derived from a comprehensive review of the specifications of commercially available vehicles (https://driving.ca/find-compare/).

[38] Module pricing is assumed for purchases made by the vehicle assembly industry from the battery manufacturing industry.

[39] Argonne National Laboratory (ANL) (2022). Battery Performance and Cost Modeling for Electric- Drive Vehicles (BatPaC).

[40] Munro & Associates (2020). *BMW i3 Cost Analysis*.

[41] UBS (2017). *UBS Evidence Lab Electric Car Teardown – Disruption Ahead?*

systems, in particular, has experienced fluctuations, influenced by advancements in battery technology, economies of scale in production, and changes in raw material costs. Looking ahead, it is expected that the price per kWh of battery packs will continue to decline significantly in the coming years. This price variability underscores the importance of accounting for the variations of battery and other vehicle component costs into production cost forecasts for each vehicle type. Such considerations are critical in understanding the impact of producing a mix of these vehicles on Canada's automotive manufacturing sector. Therefore, in FOCAL's EV forecast model, the changes in component and part prices are accounted for as a function of time, ensuring a comprehensive and dynamic approach to the economic modeling of the sector and the supply chain.

A similar approach was followed to adjust the purchasing pattern of heavy-duty truck manufacturing (NAICS 336120). Changes in component and part costs were taken into account when modeling and forecasting the cost structure of a Canadian-produced hybrid or battery-powered heavy-duty bus or truck. For heavy-duty battery-powered trucks and buses, the vehicle's cost structure was adjusted to include a 500-kWh battery, along with modifications to the powertrain and electronic components of the vehicle.

For the purpose of this study, the battery pack assembly stage was assumed to be part of the vehicle assembly stage, which includes both the light-duty vehicle manufacturing industry, as well as the heavy-duty vehicle manufacturing industry. Therefore, the cost structure of each vehicle type (and consequently, the purchases of the vehicle assembly industry) includes purchases of battery thermal and power management systems, battery jackets, and heating systems.

Working backward through the automotive and battery manufacturing supply chains, adjustments were made to the purchasing patterns of the battery manufacturing industry (NAICS 335910). To determine the necessary material purchases per unit, cost structures for both battery cells and battery modules were developed. Based on technical data of battery cell composition, four distinct cost structures were developed, each corresponding to different chemical compositions: NCA, NMC622, NMC811, and LFP. These cost structures encompass components and materials for positive and negative electrodes, current collectors, separators, and cell containers, which are common across all battery cell variations. In the case of battery modules, the cost structure accounts for components such as enclosures, power regulators, and thermal conductors.

Finally, adjustments were made to the purchasing pattern of the cathode manufacturing industry (NAICS 325180) to account for the purchases of filtered material from the material refining industry (NAICS 331410), as well as to the purchasing patterns of the anode manufacturing industry (NAICS 327990) and the material refining industry (NAICS 331410) to account for purchases from the mining sector (primarily industry NAICS 212232, 212299 and 212398).

Estimating Industry Outputs and Purchasing Patterns

Using the adjusted purchasing patterns of the automotive and battery manufacturing supply chain industries, coupled with assumptions on domestic production levels within each of the identified industries (such as the number of vehicles produced, the manufacturing volume of battery cells and modules, and the tonnes of cathode material processed – discussed in section), it is possible to estimate the total output and purchasing pattern of each of the industries within the supply chain.

For the vehicle assembly industry, the total output was estimated for each year between 2025 and 2040 by summing the products of the total number of vehicles produced (by vehicle powertrain type and size) and their respective projected total production costs. Vehicle production forecasts by powertrain types and size were derived from various projections and sources, including S&P and LMC. Since some of these projections only reached up to 2030 or 2035, it was necessary to extend the forecasts to 2040 to cover the full duration of this study's impact analysis. To extend these forecasts up to the year 2040, data extrapolation was employed using a curve-fitting method. This approach allowed for a more comprehensive and long-term projection, taking into account emerging trends and market dynamics anticipated to influence the automotive manufacturing sector over the upcoming two decades. Furthermore, using the volume of vehicles produced (by vehicle powertrain type and size) and their respective purchasing patterns, it is possible to estimate the total value of purchases made by the vehicle assembly industry from all other industries, along with the overall purchasing pattern of the industry.

The total output of the battery manufacturing industry (NAICS 335910) was estimated by considering a set of assumptions in each of the three scenarios. The assumptions include the number of operational battery plants, their individual production capacities, the year production commences for each plant, and the time needed for each plant to reach its operational capacity. The output of the industry also factored in the average price per kWh of batteries for each year, the proportion of battery cells to modules produced, as well as the market share distribution among various chemical compositions of the batteries manufactured. The total output of the battery manufacturing industry is calculated by combining the average price of each cell and module variation with the production volumes of cells and modules. This approach integrates detailed pricing and production data to accurately reflect the industry's output.

Using the developed cost structures of both battery cells and modules, it is possible to calculate the domestic economic output within each industry in the battery manufacturing supply chain (including cathode manufacturing industry (NAICS 325180), anode manufacturing industry, (NAICS 327990), material refining industry (NAICS 331410), and mining (NAICS 212232, 212299 and 212398). The economic output for each of these industries is estimated based on their assumed domestic production capacities in each scenario.

Application of IMPLAN in Measuring Broader Industry Impacts

IMPLAN (Impact Analysis for Planning) is an economic modeling system used to estimate the ripple effects of economic changes in a given area. It is a tool that can be used to assess the direct, indirect, and induced impacts[42] of economic activities on industries within a specific sector or geographic region. In the context of Canada's automotive and battery manufacturing industry's transition from ICEVs to EVs, IMPLAN can play a key role in analyzing and forecasting the full economic and employment impacts.

Utilizing the projected total outputs and the adjusted purchasing patterns developed for the industries within automotive and battery manufacturing, IMPLAN can offer insights into how shifts towards EV and battery production will impact the broader economy. By inputting the data on the projected outputs and purchasing patterns, IMPLAN can estimate the direct, indirect and induced economic and labour market implications across 234 industries in the Canadian economy.

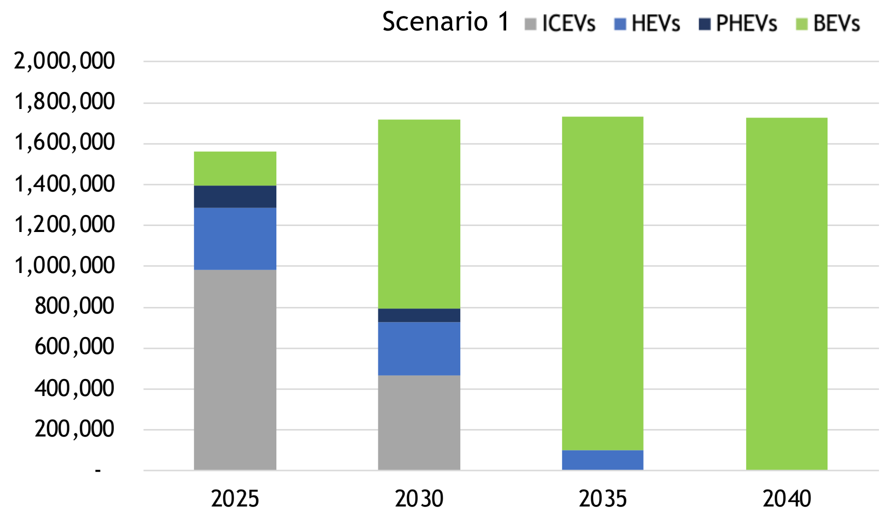
The table below maps the industries of the automotive and battery manufacturing industries to their respective North American Industry Classification System (NAICS) codes, Input-Output Industry Classification (IOIC) codes, and IMPLAN Industry codes.

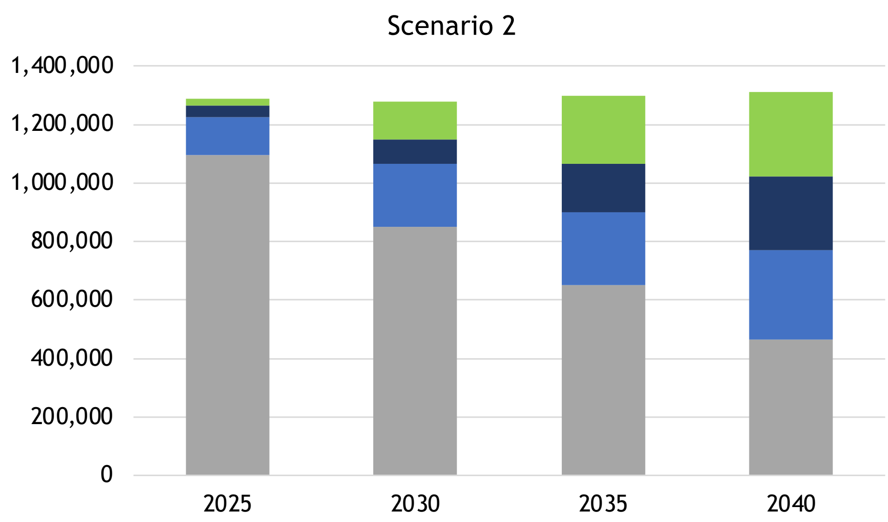
[42] Direct impacts refer to the immediate effects of changes in industries. These impacts are the primary outcomes of an industry's activities, such as the creation of jobs, the generation of output (products or services), and the revenue earned by the businesses in the sector. Indirect impacts encompass the secondary effects experienced by the supply chain linked to the primary industry. These are the ripple effects that occur as a result of the interdependencies between industries. For instance, a boost in production in one sector may increase demand for raw materials or components from suppliers, thus impacting various upstream industries. Induced impacts are the tertiary economic effects generated by the spending of incomes earned in the direct and indirect phases. These impacts occur when employees in the primary and secondary industries spend their wages on goods and services in the wider economy.

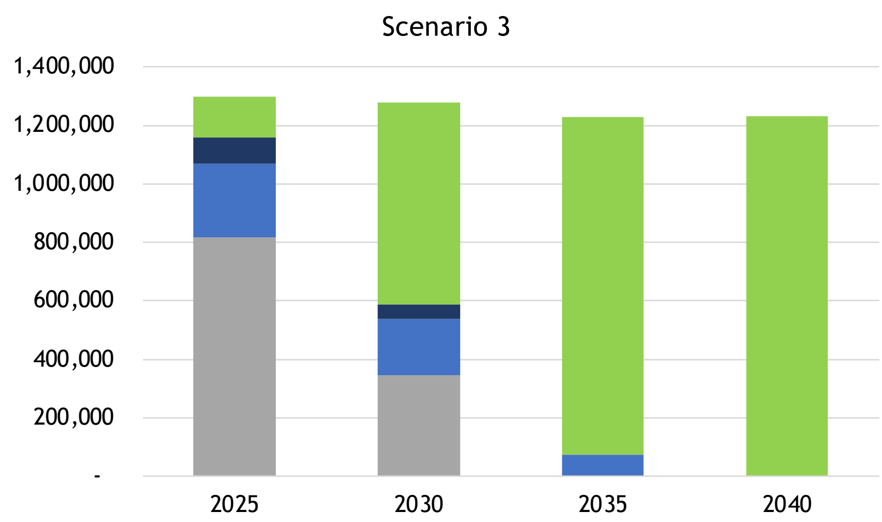
Industry	North American Industry Classification System (NAICS) Code	Input - Output Industry Classification (IOIC) Code	Industry IMPLAN Code
Vehicle Assembly			
Light-Duty Vehicle Assembly	336110 - Automobile and Light-Duty Motor Vehicle Manufacturing	BS336110	99
Heavy-Duty Bus and Truck Manufacturing	336120 - Heavy-Duty Truck Manufacturing	BS336120	100
Vehicle Parts Manufacturing			
Gasoline Engine Manufacturing	336310 - Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	BS336310	102
Vehicle Electrical and Electronics Component	336320 - Motor Vehicle Electrical and Electronic Equipment Manufacturing	BS336320	103
Steering and Suspension Parts Manufacturing	336330 - Motor Vehicle Steering and Suspension Components (Except Spring) Manufacturing	BS336330	104
Vehicle Brakes Manufacturing	336340 - Motor Vehicle Brake System Manufacturing	BS336340	105
Transmission and Powertrain Manufacturing	336350 - Motor Vehicle Transmission and Powertrain Parts Manufacturing	BS336350	106
Seat and Trim Manufacturing	336360 - Motor Vehicle Seating and Interior Trim Manufacturing	BS336360	107
Motor Vehicle Metal Stamping	336370 - Motor Vehicle Metal Stamping	BS336370	108
Other motor vehicle parts manufacturing	336390 - Other Motor Vehicle Parts Manufacturing	BS336390	109

Battery Manufacturing			
Battery Cell & Module Manufacturing	335910 - Battery manufacturing	BS335900	98
Battery Material Manufacturing / Chemical Manufacturing			
Cathode & Precursor Cathode Manufacturing	325180 - Other basic inorganic chemical manufacturing	BS325100	60
Anode Manufacturing	327990 - All other non-metallic mineral product manufacturing	BS327A00	69
Material Processing & Filtering			
Material Refining	3314 - Non-ferrous metal (except aluminum) smelting and refining	BS331400	74
Mining			
Iron Ore Mining	212210 - Iron Ore Mining	BS212210	14
Nickel Mining	212232 - Nickel-Copper Ore Mining	BS212230	16
Lithium, Cobalt and Manganese Mining	212299 - All Other Metal Ore Mining	BS212290	17
Graphite Mining	212398 - All other non-metallic mineral mining and quarrying	BS21239A	21

Appendix D. Detailed Vehicle Production Assumptions Across Three EV Transition Scenarios







	Scenario 1	Scenario 2	Scenario 3
Vehicle Production (2040)	1,728,218	1,313,180	1,232,241
Rate of Transition	Accelerated Transition	Moderate Transition	Accelerated Transition
Data Source	GlobalData Automotive Production Forecast (Adjusted & Forecast Extended)	S&P Global Automotive Production Forecast (Adjusted & Forecast Extended)	GlobalData Automotive Production Forecast S&P Global Automotive Production Forecast (Adjusted & Forecast Extended)

Appendix E. Detailed Battery Manufacturing Assumptions Across Three EV Transition Scenarios

	Scenario 1	Scenario 2	Scenario 3
Battery Production Capacity (by 2040)	202 GWh	165 GWh	202 GWh
Number of Battery Plants (by 2040)	4	3	4
Peak Operational Capacity of Battery Plant	75%	30%	75%
Years to Ramp Up Battery Production	5	5	5
Operational Battery Production Capacity (by 2040)	151.5 GWh	49.5 GWh	151.5 GWh
Individual Battery Plant Production Capacity & Year Plant Commences Production	Plant 1 (2025): 45 GWh Plant 2 (2028): 90 GWh Plant 3 (2028): 30 GWh Plant 4 (2031): 37 GWh	Plant 1 (2025): 45 GWh Plant 2 (2028): 90 GWh Plant 3 (2028): 30 GWh	Plant 1 (2025): 45 GWh Plant 2 (2028): 90 GWh Plant 3 (2028): 30 GWh Plant 4 (2031): 37 GWh
Cathode & Anode Production[43]	100%	10%	55%
Material Processing & Filtering[43]	100%	10%	55%
Mining[43,44]	100%	10%	55%
Cobalt Mining	25%	10%	25%

[43] Of battery material upstream domestic demand.

[44] Except Cobalt.

Battery Cell Type	NCA	LFP	NMC622	NMC811
Cathode Chemical Composition	Aluminum Lithium Cobalt Nickel	Iron Lithium Phosphate	Cobalt Manganese Lithium Nickel	Cobalt Lithium Nickel Manganese
Anode Chemical Composition	Graphite	Graphite	Graphite	Graphite
Market Share[45]	28%	39%	17%	17%

[45] Market share of battery cell types utilized throughout the entire forecast period. Data was derived from forecast of battery cell types by Wood Mackenzie Energy.

Battery Technical Specifications	
Number of Cells (per Pack)	320
Battery Cell Cathode Contents	Positive electrode active material Positive electrode carbon additive Positive electrode binder Positive electrode binder solvent
Battery Cell Anode Contents	Negative electrode active material Negative electrode carbon additive Negative electrode binder Negative electrode binder solvent
Current Collectors & Separators	Positive current collector Negative current collector Separators Electrolyte
Other Battery Cell Components	Cell container Positive terminal assembly Negative terminal assembly
Number of Modules (per Pack)	20
Battery Module Contents	Battery Cells Aluminum thermal conductors Cell group interconnects Module state-of-charge regulator Module terminals Module gas release Module enclosure
Battery Pack Contents	Battery thermal management system Battery power management system Battery terminals Battery jacket Heating system Module inter-connectors and signal wiring Module compression plates and steel straps Baseline thermal system

Appendix F. Detailed Output and Employment Impacts of the Three EV Transition Scenarios

Scenario 1

	Industry	Change in Output 2025	2030	2035	2040
Vehicle Assembly	**Automobile and light-duty motor vehicle manufacturing**	**$ 7,005,153,653**	**$ 21,965,527,321**	**$ 27,927,391,059**	**$ 25,733,631,525**
	Heavy-duty truck manufacturing	**$ 497,797,215**	**$ 1,113,988,333**	**$ 747,168,245**	**$ 746,094,329**
Vehicle Parts Manufacturing	Gasoline engine and engine parts manufacturing	$ (479,271,937)	$ (2,425,825,679)	$ (4,253,487,050)	$ (4,523,235,010)
	Electrical and electronic equipment manufacturing	$ 12,477,933	$ 50,191,556	$ 79,152,321	$ 84,285,672
	Steering and suspension components manufacturing	$ 24,948,977	$ 118,372,028	$ 145,070,197	$ 147,406,403
	Brake system manufacturing	$ 3,426,360	$ 16,754,639	$ 20,177,394	$ 20,736,919
	Transmission and power train parts manufacturing	$ 6,020,188	$ (87,788,538)	$ (278,396,351)	$ (311,391,339)
	Seating and interior trim manufacturing	$ (17,238,204)	$ 212,720,076	$ 199,436,810	$ 201,604,437
	Motor vehicle metal stamping	$ 40,604,186	$ 278,312,564	$ 422,313,731	$ 377,596,240
	Other motor vehicle parts manufacturing	$ 322,027,572	$ 790,255,642	$ 1,028,739,622	$ 1,032,191,531
	Total Vehicle Parts Manufacturing	**$ (87,004,925)**	**$ (1,047,007,712)**	**$ (2,636,993,326)**	**$ (2,970,805,147)**
Battery Manufacturing	Other electrical equipment and component manufacturing	$ 674,055,639	$ 7,197,533,960	$ 9,142,946,401	$ 6,701,883,734
	Total Battery Manufacturing	**$ 674,055,639**	**$ 7,197,533,960**	**$ 9,142,946,401**	**$ 6,701,883,734**
Material Processing	Basic chemical manufacturing	$ 299,203,895	$ 2,856,059,393	$ 3,620,108,013	$ 2,654,473,098
	Non-metallic mineral product manufacturing	$ 88,600,018	$ 633,165,091	$ 797,820,714	$ 627,510,572
	Non-ferrous metal production and processing	$ 231,084,096	$ 2,194,836,991	$ 2,789,596,261	$ 2,051,020,639
	Total Material Processing	**$ 618,888,009**	**$ 5,684,061,475**	**$ 7,207,524,988**	**$ 5,333,004,309**
Mining	Iron ore mining	$ 1,690,572	$ 5,181,857	$ 6,274,684	$ 5,896,215
	Copper, nickel, lead and zinc ore mining	$ 45,181,020	$ 431,466,111	$ 547,773,343	$ 401,982,112
	Other metal ore mining	$ 167,181,785	$ 1,624,301,452	$ 2,060,466,109	$ 1,506,369,349
	Other non-metallic mineral mining and quarrying	$ 32,828,288	$ 314,635,675	$ 398,848,433	$ 292,198,503
	Total Mining	**$ 246,881,665**	**$ 2,375,585,095**	**$ 3,013,362,569**	**$ 2,206,446,179**
Rest of Automotive Supply Chain	**Total Rest of Automotive Supply Chain**	**$ 1,232,143,498**	**$ 3,918,443,005**	**$ 5,086,971,696**	**$ 4,950,712,786**
Rest of Economy	**Total Rest of Economy**	**$ 2,332,767,349**	**$ 9,410,168,300**	**$ 11,137,356,484**	**$ 9,693,695,386**
Total		**$ 12,520,682,103**	**$ 50,618,299,777**	**$ 61,625,728,116**	**$ 52,394,663,101**

	Industry	Change in Employment 2025	2030	2035	2040
Vehicle Assembly	**Automobile and light-duty motor vehicle manufacturing**	**4,889**	**15,330**	**19,491**	**17,960**
	Heavy-duty truck manufacturing	**1,108**	**2,480**	**1,663**	**1,661**
Vehicle Parts Manufacturing	Gasoline engine and engine parts manufacturing	(555)	(2,808)	(4,923)	(5,235)
	Electrical and electronic equipment manufacturing	40	164	259	275
	Steering and suspension components manufacturing	43	208	254	259
	Brake system manufacturing	14	71	86	89
	Transmission and power train parts manufacturing	15	(229)	(725)	(811)
	Seating and interior trim manufacturing	(37)	451	422	427
	Motor vehicle metal stamping	66	456	692	619
	Other motor vehicle parts manufacturing	608	1,492	1,942	1,949
	Total Vehicle Parts Manufacturing	**194**	**(195)**	**(1,993)**	**(2,428)**
Battery Manufacturing	Other electrical equipment and component manufacturing	1,713	18,293	23,237	17,033
	Total Battery Manufacturing	**1,713**	**18,293**	**23,237**	**17,033**
Material Processing	Basic chemical manufacturing	179	1,717	2,176	1,596
	Non-metallic mineral product manufacturing	287	2,055	2,590	2,037
	Non-ferrous metal production and processing	46	442	562	413
	Total Material Processing	**512**	**4,214**	**5,328**	**4,046**
Mining	Iron ore mining	-	2	2	2
	Copper, nickel, lead and zinc ore mining	50	482	611	449
	Other metal ore mining	307	2,987	3,790	2,771
	Other non-metallic mineral mining and quarrying	82	795	1,007	738
	Total Mining	**439**	**4,266**	**5,410**	**3,960**
Rest of Automotive Supply Chain	**Total Rest of Automotive Supply Chain**	**3,186**	**10,487**	**13,114**	**12,560**
Rest of Economy	**Total Rest of Economy**	**10,625**	**42,870**	**50,844**	**44,259**
Total		**22,666**	**97,745**	**117,094**	**99,051**

Scenario 2

	Industry	Change in Output 2025	2030	2035	2040
Vehicle Assembly	**Automobile and light-duty motor vehicle manufacturing**	**$ (6,189,279,621)**	**$ (6,220,254,984)**	**$ 1,536,371,395**	**$ 1,171,609,799**
	Heavy-duty truck manufacturing	**$ (439,616,030)**	**$ 270,437,582**	**$ 259,381,329**	**$ 222,894,700**
Vehicle Parts Manufacturing	Gasoline engine and engine parts manufacturing	$ (120,606,621)	$ (494,588,625)	$ (826,703,691)	$ (1,023,133,602)
	Electrical and electronic equipment manufacturing	$ (6,453,028)	$ (3,184,098)	$ 12,900,959	$ 16,725,790
	Steering and suspension components manufacturing	$ (117,359,776)	$ (144,475,435)	$ (57,392,086)	$ (74,271,673)
	Brake system manufacturing	$ (17,478,205)	$ (21,602,164)	$ (8,998,493)	$ (11,351,872)
	Transmission and power train parts manufacturing	$ (168,941,385)	$ (212,104,312)	$ (134,203,436)	$ (167,702,178)
	Seating and interior trim manufacturing	$ (513,203,240)	$ (666,218,376)	$ (375,611,633)	$ (477,361,129)
	Motor vehicle metal stamping	$ (215,906,208)	$ (259,269,005)	$ (104,579,901)	$ (139,167,515)
	Other motor vehicle parts manufacturing	$ (157,020,089)	$ (102,615,411)	$ 193,818,986	$ 236,192,755
	Total Vehicle Parts Manufacturing	**$ (1,316,968,549)**	**$ (1,904,057,422)**	**$ (1,300,769,293)**	**$ (1,640,069,422)**
Battery Manufacturing	Other electrical equipment and component manufacturing	$ 200,088,407	$ 2,595,756,064	$ 2,721,496,686	$ 1,981,661,930
	Total Battery Manufacturing	**$ 200,088,407**	**$ 2,595,756,064**	**$ 2,721,496,686**	**$ 1,981,661,930**
Material Processing	Basic chemical manufacturing	$ (5,254,110)	$ 97,321,182	$ 114,689,095	$ 80,516,310
	Non-metallic mineral product manufacturing	$ (63,578,274)	$ (52,748,265)	$ 6,817,725	$ (5,970,975)
	Non-ferrous metal production and processing	$ 3,297,313	$ 30,578,351	$ 41,982,981	$ 35,060,725
	Total Material Processing	**$ (65,535,071)**	**$ 75,151,268**	**$ 163,489,801**	**$ 109,606,060**
Mining	Iron ore mining	$ (2,853,491)	$ (2,996,591)	$ (453,892)	$ (689,108)
	Copper, nickel, lead and zinc ore mining	$ 506,837	$ 18,611,062	$ 20,832,806	$ 15,553,298
	Other metal ore mining	$ 6,436,646	$ 68,905,494	$ 71,294,276	$ 51,905,816
	Other non-metallic mineral mining and quarrying	$ (35,581)	$ 11,144,972	$ 12,593,364	$ 8,952,931
	Total Mining	**$ 4,054,411**	**$ 95,664,937**	**$ 104,266,554**	**$ 75,722,937**
Rest of Automotive Supply Chain	**Total Rest of Automotive Supply Chain**	**$ (895,085,318)**	**$ (685,550,319)**	**$ 556,899,481**	**$ 567,709,344**
Rest of Economy	**Total Rest of Economy**	**$ (2,904,137,099)**	**$ (2,260,320,181)**	**$ 377,861,487**	**$ (109,865,566)**
Total		**$ (11,606,478,870)**	**$ (8,033,173,055)**	**$ 4,418,997,440**	**$ 2,379,269,782**

	Industry	Change in Employment 2025	2030	2035	2040
Vehicle Assembly	**Automobile and light-duty motor vehicle manufacturing**	**(4,320)**	**(4,342)**	**1,072**	**817**
	Heavy-duty truck manufacturing	**(979)**	**602**	**577**	**496**
Vehicle Parts Manufacturing	Gasoline engine and engine parts manufacturing	(140)	(573)	(957)	(1,185)
	Electrical and electronic equipment manufacturing	(22)	(11)	42	54
	Steering and suspension components manufacturing	(207)	(254)	(101)	(131)
	Brake system manufacturing	(76)	(93)	(39)	(49)
	Transmission and power train parts manufacturing	(440)	(552)	(350)	(437)
	Seating and interior trim manufacturing	(1,089)	(1,413)	(797)	(1,013)
	Motor vehicle metal stamping	(355)	(426)	(172)	(229)
	Other motor vehicle parts manufacturing	(297)	(194)	366	446
	Total Vehicle Parts Manufacturing	**(2,626)**	**(3,516)**	**(2,008)**	**(2,544)**
Battery Manufacturing	Other electrical equipment and component manufacturing	508	6,597	6,916	5,036
	Total Battery Manufacturing	**508**	**6,597**	**6,916**	**5,036**
Material Processing	Basic chemical manufacturing	(4)	58	68	48
	Non-metallic mineral product manufacturing	(207)	(172)	22	(20)
	Non-ferrous metal production and processing	-	6	8	7
	Total Material Processing	**(211)**	**(108)**	**98**	**35**
Mining	Iron ore mining	(2)	(2)	(1)	(1)
	Copper, nickel, lead and zinc ore mining	-	20	23	17
	Other metal ore mining	11	126	131	95
	Other non-metallic mineral mining and quarrying	(1)	28	31	22
	Total Mining	**8**	**172**	**184**	**133**
Rest of Automotive Supply Chain	**Total Rest of Automotive Supply Chain**	**(3,072)**	**(2,717)**	**821**	**646**
Rest of Economy	**Total Rest of Economy**	**(13,101)**	**(10,176)**	**1,831**	**(379)**
Total		**(23,793)**	**(13,488)**	**9,491**	**4,240**

Scenario 3

		Change in Output			
	Industry	2025	2030	2035	2040
Vehicle Assembly	**Automobile and light-duty motor vehicle manufacturing**	↓ $ (1,907,286,536)	↑ $ 4,632,732,470	↑ $ 6,574,358,705	↑ $ 5,223,325,566
	Heavy-duty truck manufacturing	↑ $ 77,947,239	↑ $ 284,336,178	↑ $ 259,278,746	↑ $ 746,094,329
Vehicle Parts Manufacturing	Gasoline engine and engine parts manufacturing	↓ $ (512,756,061)	↓ $ (2,455,338,145)	↓ $ (4,259,436,594)	↓ $ (4,524,684,518)
	Electrical and electronic equipment manufacturing	↑ $ 1,717,768	↑ $ 24,049,946	↑ $ 41,276,978	↑ $ 45,742,702
	Steering and suspension components manufacturing	↓ $ (96,982,022)	↓ $ (90,375,627)	↓ $ (97,874,197)	↓ $ (92,643,407)
	Brake system manufacturing	↓ $ (14,641,765)	↓ $ (14,047,186)	↓ $ (15,549,315)	↓ $ (14,649,457)
	Transmission and power train parts manufacturing	↓ $ (159,263,753)	↓ $ (314,761,175)	↓ $ (471,248,432)	↓ $ (484,144,149)
	Seating and interior trim manufacturing	↓ $ (493,037,909)	↓ $ (566,813,609)	↓ $ (673,661,759)	↓ $ (657,649,384)
	Motor vehicle metal stamping	↓ $ (176,495,423)	↓ $ (112,446,706)	↓ $ (90,983,525)	↓ $ (83,760,304)
	Other motor vehicle parts manufacturing	↑ $ 22,806,831	↑ $ 219,547,301	↑ $ 318,085,308	↑ $ 345,593,231
	Total Vehicle Parts Manufacturing	↓ $ (1,428,652,334)	↓ $ (3,310,185,201)	↓ $ (5,249,391,536)	↓ $ (5,466,195,286)
Battery Manufacturing	Other electrical equipment and component manufacturing	↑ $ 671,519,234	↑ $ 6,982,092,046	↑ $ 8,832,258,691	↑ $ 6,461,996,506
	Total Battery Manufacturing	↑ $ 671,519,234	↑ $ 6,982,092,046	↑ $ 8,832,258,691	↑ $ 6,461,996,506
Material Processing	Basic chemical manufacturing	↑ $ 149,413,404	↑ $ 1,553,416,104	↑ $ 1,975,651,536	↑ $ 1,437,782,448
	Non-metallic mineral product manufacturing	↓ $ (12,884,495)	↑ $ 262,410,511	↑ $ 377,526,008	↑ $ 248,936,155
	Non-ferrous metal production and processing	↑ $ 125,511,141	↑ $ 711,558,552	↑ $ 904,796,759	↑ $ 666,529,935
	Total Material Processing	↑ $ 262,040,050	↑ $ 2,527,385,167	↑ $ 3,257,974,303	↑ $ 2,353,248,538
Mining	Iron ore mining	↓ $ (1,755,200)	↓ $ (1,213,948)	↓ $ (1,393,649)	↓ $ (1,431,998)
	Copper, nickel, lead and zinc ore mining	↑ $ 24,117,388	↑ $ 239,333,358	↑ $ 303,852,314	↑ $ 222,393,410
	Other metal ore mining	↑ $ 93,228,705	↑ $ 909,907,975	↑ $ 1,153,551,793	↑ $ 843,035,342
	Other non-metallic mineral mining and quarrying	↑ $ 16,870,047	↑ $ 171,536,217	↑ $ 217,956,596	↑ $ 158,795,021
	Total Mining	↑ $ 132,460,940	↑ $ 1,319,563,602	↑ $ 1,673,967,054	↑ $ 1,222,791,775
Rest of Automotive Supply Chain	**Total Rest of Automotive Supply Chain**	↓ $ (166,875,000)	↑ $ 1,016,314,220	↑ $ 1,879,326,232	↑ $ 1,405,534,491
Rest of Economy	**Total Rest of Economy**	↓ $ (1,362,985,542)	↑ $ 1,831,662,900	↑ $ 3,030,072,638	↑ $ 1,394,401,647
Total		↓ $ (3,721,831,949)	↑ $ 15,283,901,382	↑ $ 20,257,844,833	↑ $ 13,341,197,566

		Change in Employment			
	Industry	2025	2030	2035	2040
Vehicle Assembly	**Automobile and light-duty motor vehicle manufacturing**	↓ (1,332)	↑ 3,233	↑ 4,588	↑ 3,645
	Heavy-duty truck manufacturing	↑ 173	↑ 633	↑ 577	↑ 1,661
Vehicle Parts Manufacturing	Gasoline engine and engine parts manufacturing	↓ (594)	↓ (2,842)	↓ (4,930)	↓ (5,237)
	Electrical and electronic equipment manufacturing	↑ 5	↑ 78	↑ 135	↑ 149
	Steering and suspension components manufacturing	↓ (171)	↓ (159)	↓ (173)	↓ (163)
	Brake system manufacturing	↓ (63)	↓ (61)	↓ (67)	↓ (63)
	Transmission and power train parts manufacturing	↓ (415)	↓ (820)	↓ (1,227)	↓ (1,260)
	Seating and interior trim manufacturing	↓ (1,046)	↓ (1,202)	↓ (1,429)	↓ (1,395)
	Motor vehicle metal stamping	↓ (290)	↓ (185)	↓ (150)	↓ (138)
	Other motor vehicle parts manufacturing	↑ 43	↑ 414	↑ 600	↑ 652
	Total Vehicle Parts Manufacturing	↓ (2,531)	↓ (4,777)	↓ (7,241)	↓ (7,455)
Battery Manufacturing	Other electrical equipment and component manufacturing	↑ 1,706	↑ 17,745	↑ 22,447	↑ 16,423
	Total Battery Manufacturing	↑ 1,706	↑ 17,745	↑ 22,447	↑ 16,423
Material Processing	Basic chemical manufacturing	↑ 89	↑ 934	↑ 1,188	↑ 864
	Non-metallic mineral product manufacturing	↓ (42)	↑ 851	↑ 1,225	↑ 808
	Non-ferrous metal production and processing	↑ 25	↑ 143	↑ 182	↑ 134
	Total Material Processing	↑ 72	↑ 1,928	↑ 2,595	↑ 1,806
Mining	Iron ore mining	↓ (1)	↓ (1)	↓ (1)	↓ (1)
	Copper, nickel, lead and zinc ore mining	↑ 26	↑ 267	↑ 339	↑ 248
	Other metal ore mining	↑ 171	↑ 1,673	↑ 2,121	↑ 1,550
	Other non-metallic mineral mining and quarrying	↑ 42	↑ 433	↑ 550	↑ 401
	Total Mining	↑ 238	↑ 2,372	↑ 3,009	↑ 2,198
Rest of Automotive Supply Chain	**Total Rest of Automotive Supply Chain**	↓ (1,142)	↑ 1,712	↑ 3,789	↑ 2,139
Rest of Economy	**Total Rest of Economy**	↓ (6,108)	↑ 8,541	↑ 14,022	↑ 6,568
Total		↓ (8,924)	↑ 31,387	↑ 43,786	↑ 26,985

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