TRILLIUM NETWORK
FOR ADVANCED MANUFACTURING

PREPARED FOR CLEAN ENERGY CANADA

SEPTEMBER 2022

Developing Canada's Electric Vehicle Battery Supply Chain: Quantifying the Economic Impacts and Opportunities

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ABOUT THE TRILLIUM NETWORK FOR ADVANCED MANUFACTURING

The Trillium Network for Advanced Manufacturing is a provincially-funded non-profit organization dedicated to raising public and investor awareness of Ontario's advanced manufacturing ecosystem.

The Trillium Network is governed by a board of directors chaired by Ben Whitney and is managed by Brendan Sweeney. Its offices are located at Western University in London, Ontario. Trillium Network staff work closely with all levels of government, industry associations, manufacturers, educational institutions, and other like-minded partners across the province.

To learn more about the Trillium Network please visit trilliummfg.ca.

EXECUTIVE SUMMARY

Countries across the world have begun the transition away from fossil fuel-dependent internal combustion engine vehicles (ICEVs) and towards EVs. As the transition to EVs accelerates, the demand for batteries and the minerals used to manufacture rechargeable batteries that propel EVs is expected to increase considerably.

The World Bank estimates that the global demand for EV battery minerals–such as graphite, lithium, and cobalt–will increase four to five times by 2050 while the demand for nickel will double. Others, such as the International Energy Agency, estimate that demand for certain minerals, and specifically lithium, could increase sixfold by 2030. Disruptions arising from the COVID-19 pandemic and more recently, the invasion of Ukraine by Russia, underscore the fragility of global supply chains. They also demonstrate that building a reliable EV battery mineral supply chain is strategically important. As a result, jurisdictions around the world are seeking to develop and grow EV battery supply chains.

Canada has the potential to play an important role in the growing global battery market. It features unique assets and competitive advantages related to the EV battery supply chain, including access to critical minerals, a skilled and talented workforce, a comprehensive manufacturing ecosystem, supportive public policies, environmental and regulatory frameworks, access to international markets, clean energy, and R&D and innovation. Canada has also taken some important steps to advance its battery industry, from the $3.8 billion plan to support the mining industry outlined in the recent federal budget to the suite of other policies and programs provincial governments have implemented to encourage further development of the EV battery supply chain. As a result, 2022 saw a string of exciting announcements of companies making significant investments across the battery supply chain.

While much progress has been made, even more work remains to be done. Activity along the EV battery supply chain in Canada is still limited. The policies and programs supporting the EV battery supply chain tend to be ad hoc. Canada must act quickly, strategically and ambitiously to unlock the full potential of its battery supply chain. To do so, we need a better understanding of the potential economic benefits associated with the EV battery supply chain, where along the supply chain Canada is best-positioned to compete, and the measures necessary to unlock these high priority opportunities.

This report quantifies the potential benefits associated with a battery supply chain in Canada by 2030 across four different scenarios representing increasing levels of government ambition. It focuses on battery electric (BEV) and plug-in hybrid electric (PHEV) light-duty vehicles (LDVs), including passenger cars, SUVs, minivans, and pickup trucks and on on-road medium and heavy-duty vehicles (MHDVs), including buses and trucks. It does not consider the economic impact of mild hybrid vehicles or of electrified marine, off-road, industrial, or aerospace-related vehicles. Nor does it consider hydrogen fuel cells, consumer products (e.g. power tools), energy storage systems, or R&D activities. The report focuses primarily on the North American market for EVs and value-added products related to the EV battery supply chain.

This report finds that building a battery supply chain in Canada could directly contribute between $5.7 billion to $24 billion in GDP by 2030 annually, supporting between 18,500 and 81,000 direct jobs, depending on how quickly and ambitiously Canadian governments act. These figures grow to between $15 billion and $59 billion in annual GDP contributions, and 79,000 and 333,000 jobs, when indirect and induced activities and jobs are included. Once realized, these activities would contribute between $2.7 billion and $11 billion annually in combined federal and provincial government revenues.

Finally, this report identifies three priority opportunities where Canada is best positioned to compete for investment and where the economic benefits are greatest:

- EV Assembly: Transitioning all vehicle assembly plants in Canada from assembling ICEVs to EVs exclusively sometime in the 2030s, which would translate into nearly two million electric vehicles annually, and leveraging these existing assembly plants to incentivize additional investments across the supply chain.
- EV Battery Cell Manufacturing: Securing one or two more of the few remaining EV battery cell production facilities to be announced in North America by 2030 to anchor other elements of the EV battery supply chain, such as battery component and module manufacturing, and emerge as an important contributor in this vital portion of the EV battery supply chain.
- Integrated Battery Materials Manufacturing: Creating an integrated battery materials manufacturing industry, in which Canadian-mined minerals are further refined and processed into EV battery materials in nearby production facilities, tapping Canada's most unique competitive advantage–known reserves of EV battery minerals, well-developed mining and automotive industries and a stable and democratic political environment that features strong ESG principles.

Unlocking these opportunities and sustaining the momentum created by recent EV and battery announcements through 2030 requires between $5.2 billion and $58.4 billion in additional capital expenditures beyond those that have already been committed (with approximately $520 million to $12 billion of this investment coming from Canadian governments). This would be in addition to any spending associated with infrastructure, workforce development, and tax incentives.

In addition to further investments, Canada must implement results-based policies and programs that provide both general and targeted supports to companies across the EV battery supply chain. These policies and programs should focus on the following: workforce development, technology adoption, securing EV assembly mandates, industrial land, infrastructure (including road networks and clean energy), support for industry restructuring, trade and export development, and inter-governmental collaboration and capacity-building.

What this analysis shows is that Canada can establish itself as a major contributor to the global EV battery industry. However, seizing the economic opportunities identified in this report will not happen unless Canada is proactive, building on its competitive advantages and being strategic in its investments and policies. The potential is there - Canada must choose to seize it.

SECTION 1: INTRODUCTION

The era of the electric vehicle (EV) is upon us. Countries across the world have begun the transition away from fossil fuel-dependent internal combustion engine vehicles (ICEVs) and towards EVs. This is done largely as a means to reduce the carbon footprint associated with transportation and automobility.

The most significant distinction between ICEVs and EVs is their propulsion systems. The most important (and costly) component of an ICEV is its powertrain, which relies on fossil fuels to provide power. Conversely, the most important component of an EV is its battery, which provides power to a series of motors and related propulsion systems. For these reasons, and others discussed in a recent Clean Energy Canada report,[1] jurisdictions around the world are seeking to develop and grow EV battery supply chains. In China, for example, the proliferation of EVs over the past decade is a result of both a guiding industrial policy and a response to the environmental costs associated with rapid economic development.[2] Similarly, both the EU and the United States have released comprehensive strategies in recent years to secure access to critical minerals and build domestic EV battery supply chains and are aggressively courting related investments.[3]

The pace at which other countries have adopted strategies to develop their EV battery supply chains varies. Despite its mineral wealth, high rates of vehicle ownership, and substantial automotive manufacturing footprint, Canada only recently began to develop strategies to leverage these competitive advantages for the benefit of the economy and the environment alike. These strategies have generally been developed piecemeal and vary considerably across jurisdictions (i.e. the federal and provincial governments).

Yet optimism regarding Canada's EV battery supply chain abounds. Canada features unique assets and competitive advantages related to the EV battery supply chain. These include access to international markets, access to critical minerals, a skilled and talented workforce, a comprehensive manufacturing ecosystem, supportive public policies, environmental and regulatory frameworks, clean energy, and R&D and innovation. This combination of competitive advantages offers value to a diverse range of stakeholders.

In Canada, the number of private sector investments in EV battery-related manufacturing and vehicle assembly increased significantly in the first half of 2022. The federal government and several provincial governments have announced their intentions to use policy levers to develop

[1] Clean Energy Canada (2021) 'Turning Talk into Action: Building Canada's Battery Supply Chain', https://cleanenergycanada.org/wp-content/uploads/2021/05/Turning-Talk-into-Action_ Building-Canadas-Battery-Supply-Chain.pdf.

[2] Masiero, G, M. Ogsavara, A. Jussani, and M. Risso (2016) 'Electric Vehicles in China: BYD Strategies and Government Subsidies', *Journal of Administration and Innovation* 13(1): 3-11.

[3] US Department of Commerce (2020) 'A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals', https://www.commerce.gov/sites/default/files/2020-01/Critical_Minerals_Strategy_Final.pdf; European Commission (2020) 'Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0474

battery-related mineral assets and leverage Canada's existing automotive supply chain to attract further investment. Many of these same governments have also implemented policies and programs to develop infrastructure and support consumer EV purchases.

While much progress has been made, even more work remains to be done. The policies and programs supporting the EV battery supply chain tend to be ad hoc. No comprehensive national strategy exists. Moreover, the potential economic benefits associated with the EV battery supply chain, a clear and realistic value proposition, the policies necessary to support further investment, and the places where Canada is best positioned to compete continentally and globally are not well articulated.

This report, which represents a collaboration between Clean Energy Canada and the Trillium Network for Advanced Manufacturing, addresses these gaps. More specifically, the report:

a. Identifies the opportunities and quantifies the potential benefits associated with a battery supply chain in Canada, with a focus on on-road EVs, by 2030;

b. Develops a value proposition that draws upon Canada's unique assets and competitive advantages to illustrate the value offered to private sector stakeholders across the EV battery supply chain and to government;

c. Identifies and quantifies the types, value, and mechanisms necessary to support further investment in an EV battery supply chain in Canada; and

d. Identifies Canada's highest potential opportunities and where along the supply chain Canada is best positioned to compete.

To do so, the report draws upon an economic impact analysis derived from a model developed by the Trillium Network. This model is inspired by the U.S. Department of Energy's Argonne National Laboratory's Battery Performance and Cost (BatPaC) modelling tool but has been further developed to include all nodes of the EV battery supply chain.[4] More information on the Trillium Network's model is provided in Section 3. The model is then deployed to quantify the potential economic impacts associated with each node of the supply chain and with four scenarios designed by the Trillium Network and Clean Energy Canada in consultation with members of the Canadian Battery Task Force, an industry-led coalition created to advance Canada's domestic battery industry.[5]

The remainder of the report is organized as follows. Section 2 provides background information related to investments in Canada's EV battery supply chain to date and reviews government policies and programs designed to support further investments. Section 3 provides an overview of the methodology and scenario design. Section 4 quantifies the potential economic impact of the entire EV battery supply chain in four different scenarios, each more ambitious than the last. Section 5 provides a node-by-node analysis, which describes the characteristics of each node of the EV battery supply chain and the potential economic impacts associated with each.

[4] Argonne National Laboratory (2022) 'BatPaC: Battery Manufacturing Cost Estimation', https://www.anl.gov/partnerships/batpac-battery-manufacturing-cost-estimation

[5] Accelerate (2022) 'Canadian Battery Task Force', https://acceleratezev.ca/canadian-battery-task-force/

Section 6 presents a value proposition that identifies Canada's competitive advantages generally and as they relate to each node. Section 7 identifies three priority opportunities with the greatest potential economic impact and where Canada is best positioned to compete. Section 8 examines the value and nature of the investment necessary to unlock opportunities across the EV battery supply chain, identifies the types of policy measures that can support such investments, and assesses where Canada's greatest opportunities lie. Section 9 concludes the report, highlighting the urgent need for the governments to develop a national strategy that supports EV assembly, EV battery cell manufacturing, and an integrated EV battery materials industry.

SECTION 2: BACKGROUND

Motor vehicle manufacturing has long been a critical component of Canada's economy. This is especially true in southern Ontario, Winnipeg, and parts of Québec. Canadian vehicle manufacturing grew in each decade between the 1960s and 1990s, with production peaking at more than three million units in 1999. Until then, vehicle manufacturers produced ICEVs exclusively. As the industry restructured in the early 2000s, vehicle manufacturers and parts producers began to consider integrating more environmentally-friendly technologies into their products as a means to reduce their carbon footprint.

General Motors of Canada's (GM) 2005 Beacon Project was among the first to publicly identify environmentally-friendly vehicle technologies as part of the way forward for the industry in Canada.[6] In the initial stages of this transition, however, these technologies were associated primarily with lightweight materials and fuel efficiency. Around the same time, the Government of Canada created Sustainable Development Technology Canada (SDTC), which supports the development of clean technologies.[7] While SDTC is not exclusively focused on the transportation sector, it provides funding to companies involved in the development and demonstration of EV batteries, EV components, and fuel cells.

The trajectory towards a more environmentally sustainable motor vehicle manufacturing industry in Canada was interrupted by the economic downturn of 2008 and 2009. Large automakers with operations in Canada, such as GM and Chrysler, restructured their global operations with the financial support of Canadian and U.S. governments. Several Canadian-owned companies that had invested heavily in lightweight and more environmentally-friendly parts and component manufacturing–most notably Burlington Technologies–found themselves in dire financial circumstances as their automaker customers focused on manufacturing ICEV pickup trucks, minivans, and SUVs.[8]

As the economy recovered in the early 2010s, several projects laid the foundation for the development of a Canadian EV battery supply chain. Most were focused on vehicle assembly. Toyota and Tesla jointly developed and produced approximately 2,500 units of a RAV4 battery electric vehicle (BEV) in the former's Woodstock, Ontario assembly plant in 2011 and 2012.[9] While their partnership with Tesla was short-lived, Toyota, the largest vehicle manufacturer in Canada, began producing hybrid versions of the Lexus RX in 2014 and RAV4 in 2016.[10] The company continues to produce hybrid vehicles in Woodstock and Cambridge, Ontario today. Fiat-Chrysler (now Stellantis) began producing hybrid versions of the Pacifica minivan in

[6] Government of Canada (2005) 'Government of Canada Announced $200 Million for Innovative GM Beacon Project', https://www.canada.ca/en/news/archive/2005/03/government-canada-announces-200-million-innovative-gm-beacon-project.html

[7] https://www.sdtc.ca/en/

[8] BDO (2009) 'In the Matter of the Receivership of Burlington Technologies Inc.', https://www.bdo.ca/BDO/media/Extranets/bti/Notice-and-Statement-of-Receiver.PDF

[9] Toyota Canada (2011) 'Toyota Announces Decision to Build RAV4 Electric Vehicle at Toyota's Woodstock, Ontario Production Facility', http://media.toyota.ca/releases/toyota-announces-decision-to-build-rav4-electric-vehicle-at-toyotas-woodstock-ontario-production-facility

[10] Toyota Canada, 'The RX 450h - a Luxury Hybrid, Proudly Made in Canada', http://media.toyota.ca/stories/the-rx-450h-a-luxury-hybrid-proudly-made-in-canada

Windsor, Ontario in 2016.[11] However, none of the batteries associated with any of these vehicles and only a small proportion of EV-related components were manufactured in Canada.

Several Canadian bus manufacturers produced electrified models following the economic downturn. Québec's Nova Bus, a Volvo Group subsidiary, began producing hybrid-electric buses in the early 2010s. As part of this initiative, several battery and component suppliers, including Dana TM4 (originally a spin-off of Hydro-Québec's R&D centre) and solid-state lithium-ion battery manufacturer Bathium (now Blue Solutions, a subsidiary of the Bollore Group), established manufacturing facilities with the support of the Québec government.[12] Both continue to supply bus manufacturers from their Québec facilities. Winnipeg-based New Flyer Industries began developing and demonstrating hybrid-electric and fuel cell electric vehicles, and eventually developed a battery-electric model for use in municipal transit fleets in the same decade.[13] Québec's Lion Electric Company (initially branded as Autobus Lion) launched its battery-electric eLion in 2015.[14] The eLion relies on a Québec-made TM4 electric motor and imported LG lithium-ion batteries.

Despite these initial investments, Canada entered the 2020s with considerable uncertainty regarding the future of its EV battery supply chain. A growing number of EV battery and assembly investments were announced in the United States in the latter part of the 2010s, with few equivalent investments announced in Canada. Canadian-based bus manufacturers were increasingly compelled to shift production to larger facilities in the United States in order to satisfy 'Buy America' requirements related to government purchases in that country.[15] Similarly, several large Canadian-owned automotive parts manufacturers (e.g. Magna, Linamar) made significant investments in EV component development and manufacturing in Michigan rather than their home jurisdiction of Ontario.

The narrative began to shift as the Detroit-based automakers (Ford, General Motors, and Fiat-Chrysler/Stellantis) entered collective bargaining in the summer of 2020. These negotiations resulted in commitments by each automaker to manufacture EVs in their Canadian assembly plants.[16] Canada received further investments in 2021. New Flyer unveiled new BEV models, including the Xcelsior CHARGE and the D45 CRT LE CHARGE (through its subsidiary Motor

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[11] Macaluso, G. (2016) 'WAP Begins Production of Pacifica Hybrid Minivan,' *The Windsor Star*, https://windsorstar.com/news/local-news/wap-begins-production-of-pacifica-hybrid-minivan

[12] Dana TM4 (2012) 'Electric Bus Project is Launched in Québec,' https://www.danatm4.com/news-events/electric-bus-project-launched-Québec/

[13] New Flyer Industries (2018) 'Annual Information Form', https://www.nfigroup.com/static-files/416ea93d-a4a9-4c02-9307-933998e804db

[14] Field, K. (2016) 'Lion Bus Shows Off the New ELion Electric School Bus,' *Clean Transport*, https://cleantechnica.com/2016/05/17/elion-shows-off-new-electric-school-bus/

[15] Government of Canada, 'The Buy American Act and Buy American Requirements,' https://www.tradecommissioner.gc.ca/sell2usgov-vendreaugouvusa/procurement-marches/buyamerica.aspx?lang=eng

[16] The Canadian Press (2021) 'Unifor Approves $1 Billion General Motors Deal to Build Electric Vans in Southern Ontario', *Global News,* https://globalnews.ca/news/7582663/unifor-vote-results-general-motors-electric-vechicles-ingersoll-ontario/

Coach Industries).[17] Lion Electric announced its intention to build a battery pack and module manufacturing facility near Montréal.[18] BritishVolt announced its intentions to build an integrated EV battery cell, cathode, and anode manufacturing facility in Québec (although the timeline is unclear)[19] and the Ontario-based StromVolt unveiled plans to manufacture lithium-ion battery cells in Québec in partnership with Taiwan's Delta Electronics.[20] Magna, Canada's largest manufacturing employer, announced its new contract to supply battery enclosures for the Ford F-150 Lightning from its Ontario facilities.[21] The economic benefits associated with these (potential) investments, however, remain relatively small when compared to much larger investments that were being announced on a seemingly weekly basis in the United States in the latter part of 2021.

Canada's fortunes improved early in 2022. Honda announced that it would retool its Alliston, Ontario, assembly complex to produce hybrid versions of the CR-V in 2023.[22] BASF and General Motors (together with its joint venture partner POSCO Chemicals) each announced investments in large battery material production facilities in Bécancour, Québec.[23] Stellantis subsequently announced two major investments in Ontario. The first is a joint venture with LG Energy Solutions to invest $5 billion in a battery cell manufacturing facility in Windsor. This facility, which will employ 2,500 people when it comes online in 2024, is heralded as a turning point for the future of Canada's EV battery supply chain. Stellantis subsequently revealed plans to install flexible production lines that can produce all-electric and hybrid electric vehicles in its Windsor and Brampton, Ontario, assembly plants in the near future.[24]

Governments across Canada have implemented programs to support these investments and have announced their intentions to encourage further development of the EV battery supply chain through additional policy measures. These policies and programs are focused on battery

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[17] New Flyer Industries (2021) 'New Flyer Unveils its Most Advanced EV Bus for Mass Mobility Urban Markets', https://www.nfigroup.com/news-releases/news-release-details/new-flyer-unveils-its-most-advanced-ev-bus-mass-mobility-urban

[18] Lion Electric (2021) 'Lion Electric Announces the Construction of its Battery Manufacturing Plant and Innovation Center in Québec,' https://thelionelectric.com/img/medias/Press-release_battery-plant_FINAL_EN.pdf

[19] Electric Autonomy Canada (2021) 'BritishVolt Reveals Plans for 60GWh Canadian Battery Cell Factory, Cathode and Anode Production, and R&D Centre', https://electricautonomy.ca/2021/10/07/britishvolt-canada-battery-cell-factory/

[20] Electric Autonomy Canada (2021) 'StromVolt Unveils "Mission" to Build Canada's First Large-Scale EV Battery Cell Manufacturing Plant', https://electricautonomy.ca/2021/10/05/stromvolt-battery-cell-manufacturer-qc/

[21] Magna International (2021) 'Magna Helps Ford Electrify the Future with Battery Enclosures for F-150 Lightning', https://www.magna.com/company/newsroom/releases/release/2021/11/09/news-release---magna-helps-ford-electrify-the-future-with-battery-enclosures-for-f-150-lightning

[22] CTV News (2022) 'Alliston Honda Plant Receives $1.38 Billion to Upgrade Operations,' https://barrie.ctvnews.ca/alliston-honda-plant-to-receive-1-38-billion-to-upgrade-operations-1.5820564

[23] Kennedy, D. (2022) 'How Two Battery Materials Plants Lay the Foundation of Canada's EV Battery Industry,' *Automotive News Canada*, https://canada.autonews.com/electric-vehicles/how-two-battery-materials-plants-lay-foundation-canadas-ev-battery-industry

[24] Waddell, D. (2022) 'Stellantis Announces $3.6B Investment in Windsor, Brampton Plants,' *The Windsor Star*, https://windsorstar.com/news/local-news/stellantis-announces-3-4-billion-investment-in-ontario-plants

and EV manufacturing, EV battery mineral mining, EV charging infrastructure, EV-related innovation and R&D, and consumer adoption.

The federal government and several provinces have announced battery mineral strategies and some have attached funding specifically for these programs. They include Québec's *Strategie Québecoise de development de la filiere batterie*[25] and the second phase of Ontario's *Driving Prosperity*[26] plan. Ontario, Québec, and the federal government support manufacturing-related investments throughout the supply chain with both targeted and discrete funding programs. Several programs that fund EV-related research and innovation were recently re-capitalized (e.g. SDTC, NGen), while others were implemented recently (e.g. NRCan's Critical Battery Minerals Centre of Excellence). Table 2.1 provides a list of select government programs that support the development of the EV battery supply chain.

The federal government and some provinces have also implemented programs to support the adoption of EVs by consumers. These include support for charging infrastructure in public and private locations, as well as rebates for the purchase of certain EVs (Table 2.2). Note that the federal incentive for EV purchases can be combined with provincial incentives in most cases.

Incumbent industry associations such as the Automotive Parts Manufacturers' Association (APMA) and emerging organizations such as Accelerate have developed innovative programs to advance the EV battery agenda across Canada. All the while, economic development professionals at all three levels of government have focused their efforts on attracting further investments across the EV supply chain.

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[25] https://www.economie.gouv.qc.ca/bibliotheques/strategies/strategie-Québecoise-de-developpement-de-la-filiere-batterie/

[26] https://www.ontario.ca/page/driving-prosperity-future-ontarios-automotive-sector

Table 2.1 - Select Government Support for EV Battery Supply Chain Investment

Jurisdiction	Policies and Programs
Federal	● Strategic Innovation Fund (SIF) ● SIF Net Zero Accelerator Initiative ● Regional Development Programs (e.g. FedDev, FedNor, CED, ACOA) ● Critical Mineral Exploration Tax Credit ● Critical Minerals Research, Development and Demonstration Program ● Tax Reduction for Zero-Emission Technology Manufacturing ● Sustainable Development Technology Canada (SDTC) Clean Tech Fund ● Mineral Exploration Tax Credit (METC) ● NGen Manufacturing Supercluster Funding ● Zero Emission Vehicle Infrastructure Program ● Electric Vehicle Infrastructure Demonstration (EVID) Program ● Natural Resource Canada Critical Battery Minerals Centre of Excellence
Ontario	● Invest Ontario Funding ● Advanced Manufacturing and Innovation Competitiveness (AMIC) Program ● Northern Ontario Heritage Fund Corporation (NOHFC) ● Eastern Ontario Development Fund (EODF) ● Southwestern Ontario Development Fund (SWODF) ● Ontario Automotive Modernization Program (O-AMP) ● Ontario Vehicle Innovation Network (OVIN) ● Ontario Focused Flow-Through Share (OFFTS) Tax Credit ● Ontario Junior Exploration Program (OJEP) ● Resource Revenue Sharing (RRS) Agreements ● Aboriginal Participation Fund (APF)
Québec	● Investissement Québec Economic Development Fund ● Natural Resources and Energy Capital Fund ● Electrification and Climate Change Support ● Roulez Vert (Drive Green) Program
British Columbia	● CleanBC Go Electric Advanced Research and Commercialization Program ● Innovative Clean Energy (ICE) Fund ● CleanBC Go Electric Program
New Brunswick	● Junior Mining Assistance Program (NBJMAP) ● Prospector Assistance Program (NBPAP) ● Prospector Promotion Program ● Mineral Exploration Expense Tax Deduction ● Climate Change Fund
Saskatchewan	● Mineral Exploration Tax Credit and Rebate ● Mineral Processing Incorporate Tax Rebate

Table 2.2 - Consumer Incentives for EVs [27]

Jurisdiction	New	Used
Federal	$5,000	n/a
Alberta	n/a	n/a
British Columbia	$3,000	PST Exemption
Manitoba	n/a	n/a
New Brunswick	$5,000	$2,500
Newfoundland & Labrador	$2,500	$2,500
Nova Scotia	$3,000	$2,000
Ontario	n/a	n/a
Prince Edward Island	$5,000	$5,000
Québec	$7,000	$3,500
Saskatchewan	n/a	n/a
Yukon	$5,000	Shipping Discounts

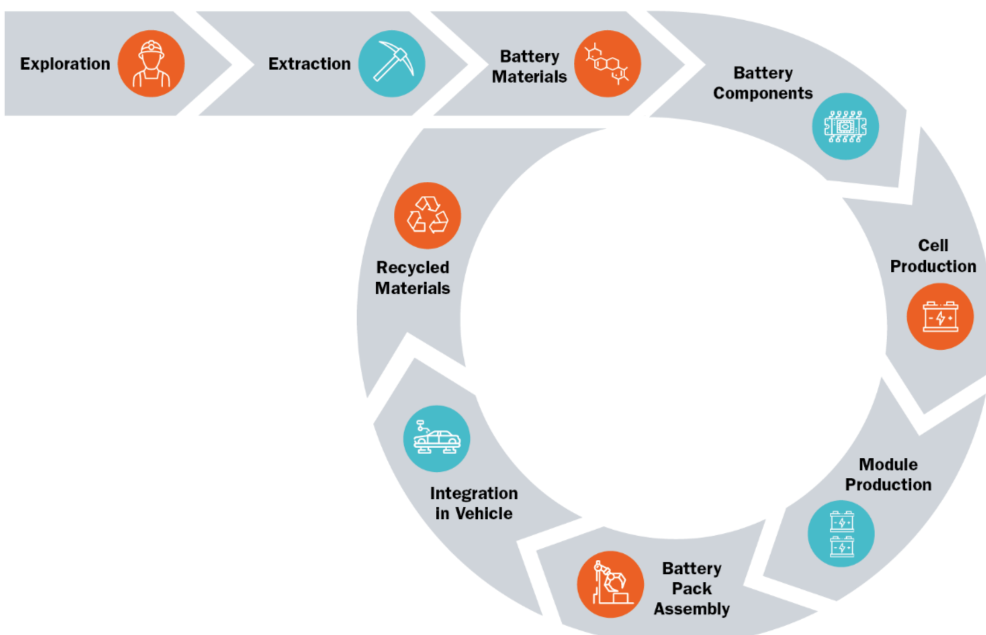
[27] For more information see: https://www.caa.ca/sustainability/electric-vehicles/government-incentives/

SECTION 3: METHODOLOGY AND SCENARIO DESIGN

3.1 - Methodology

One of the primary purposes of this report is to quantify the potential economic impact of the EV battery supply chain in Canada. This is achieved through both a node-by-node and a scenario-based analysis of the broader EV battery supply chain as defined by Clean Energy Canada (see Figure 3.1).[28] These nodes include 1) mineral exploration, 2) mining, 3) battery material production, 4) battery component manufacturing, 5) battery cell production, 6) battery module production, 7) battery pack assembly, 8) EV assembly, and 9) battery recycling. The project primarily focuses on the North American market for EVs and value-added products related to the EV battery supply chain. While the focus is on North America, it is worth noting that Mexican demand for EVs is expected to be negligible for the foreseeable future. Our analysis is thus limited primarily to Canada and the United States.

Figure 3.1 - EV Battery Supply Chain Nodes



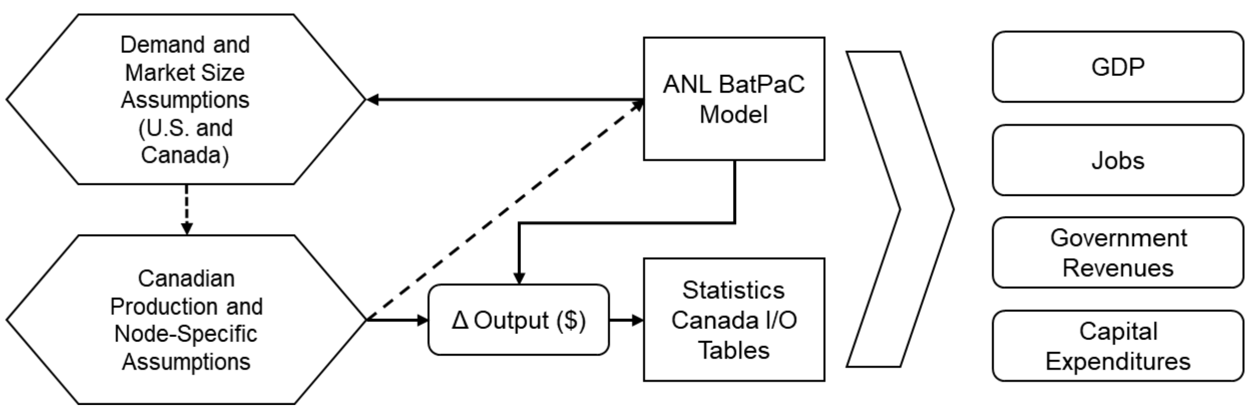
Our analysis focuses on battery electric (BEV) and plug-in hybrid electric (PHEV) light-duty vehicles (LDVs), including passenger cars, SUVs, minivans, and pickup trucks and on-road medium and heavy-duty vehicles (MHDVs), including buses and trucks. It does not consider the economic impact of mild hybrid vehicles or of electrified marine, off-road, industrial, or

[28] Clean Energy Canada (2021) 'Turning Talk into Action: Building Canada's Battery Supply Chain', https://cleanenergycanada.org/wp-content/uploads/2021/05/Turning-Talk-into-Action_ Building-Canadas-Battery-Supply-Chain.pdf.

aerospace-related vehicles. Nor does it consider hydrogen fuel cells, consumer products (e.g. power tools), energy storage systems, or R&D activities.

To conduct this analysis, the Trillium Network for Advanced Manufacturing developed an economic impact model. The model is novel in its approach in that it allows for single-node analysis as well as analysis across the entire EV battery supply chain. Figure 3.2 provides a schematic of this model. The model estimates output for each node of the supply chain in 2030 based on a set of assumptions detailed in Appendices I, II, and III, and uses these estimates to quantify the impacts on GDP, employment, and government revenues. It also quantifies the capital expenditures necessary to generate the amount of estimated output at each node of the supply chain beyond those that have been announced to date. These estimates focus specifically on private sector capital expenditures, and do not include investments in infrastructure or workforce development, which will be in some cases substantial and are likely to be borne primarily by governments. The 2030 timeline was chosen to focus on near-term opportunities, create a sense of urgency among stakeholders, and provide the necessary first steps towards a national EV battery strategy. It was also chosen due to the record pace at which investments are being announced and to support the validity of an economic model.

Figure 3.2 - Trillium Network EV Battery Supply Chain Model



The model draws extensively upon the fourth version of the U.S. Department of Energy's Argonne National Laboratory's (ANL) Battery Performance and Cost (BatPaC) model[29] and Statistics Canada's Symmetric Input-Output Tables.[30] The BatPaC model was used primarily to quantify the economic impact associated with battery cells, battery modules, and battery pack assembly. The model was modified to reflect output in Canadian dollars and for Canadian full-

[29] The BatPaC v4.0 model was released in October 2020. The ANL has been developing the model since 2007 and upgrading it regularly to incorporate the latest supply chain linkages and dynamics. For more information see: https://doi.org/10.2172/1503280 and https://www.anl.gov/partnerships/batpac-battery-manufacturing-cost-estimation

[30] For more information on Canadian Symmetric Input-Output Tables see: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=1401 and https://www150.statcan.gc.ca/n1/en/catalogue/15-207-X.

time equivalent (FTE) employment. The BatPaC model also formed the basis for a series of assumptions related to mineral requirements in different battery types (i.e. battery chemistry), battery component prices, and recyclable content in end-of-life batteries. Further detail relating to these assumptions is available in Appendix I.

Statistics Canada's Symmetric Input-Output Tables were used to construct a Leontief input-output model to establish inter-industry transactional relationships between 234 industries. This allowed us to quantify direct output and subsequently GDP, employment, government revenues, and economic multipliers for each industry in direct, indirect, and induced activities. The scope of the Trillium Network's multi-industry model required that we adjust results obtained for each node to avoid overestimating economic contributions found in related nodes of the supply chain. This was especially important when considering the economic impact associated with 'adjacent' upstream and downstream activities. This level of caution was informed by the challenges documented by the Center for Automotive Research (CAR) that were associated with past models of the automotive industry in the United States.[31] Further detail on these industry-to-industry relationships is available in Appendix II.

The Trillium Network's model used a series of assumptions to project the estimated changes in output at each node (with the exception of those derived from the BatPaC model) to operationalize the adjusted industry multipliers derived via the process noted above. These assumptions, of which further detail is available in Appendix III, are based on information obtained from publicly available sources. These sources include government and company documents as well as the Trillium Network's database of manufacturers and technology providers active across Canada's EV battery supply chain. Relying primarily on information obtained from publicly available sources limits the ability to include speculative projections or those that originate from third-party sources.

For example:

- To estimate mining output we reviewed operational and announced battery mineral projects across Canada. The production capacities identified by each company involved in these projects were multiplied by commodity price forecasts to obtain output estimates. Similarly, additional capital expenditures for mining projects (not including those already committed or realized) were based on information available in company documents, which are themselves based on the company's anticipated output. The estimated outputs were then applied to the Leontief input-output model to obtain economic impact indicators. A similar process was used for battery materials.
- A different approach was used to estimate the output associated with mineral exploration. This was due to the lack of publicly available information provided by companies involved in exploration. Instead, the Trillium Network's model draws upon the

[31] See CAR Group (2015) 'Contribution of the Automotive Industry to the Economies of All Fifty States and the United States', (Page 2, Footnote 2), https://www.cargroup.org/wp-content/uploads/2017/02/Contribution-of-the-Automotive-Industry-to-the-Economies-of-All-Fifty-States-and-the-United-States2015.pdf

historical proportion of output related to industry code BS21311B (Support Activities for Mining) relative to output related to industry code BS212 (Mining and Quarrying, Except Oil and Gas). This ratio was then used to calculate mineral exploration output based on EV battery-related mining output. Further detail is available in Appendix III.

- To estimate battery material production and recycling output, the Trillium Network's model draws upon battery material commodity price assumptions (see Appendix III) and in some cases assumptions related to Canada's market share in North America for battery material production and recycling (see Appendix IV).
- To estimate EV assembly output we multiplied the projected number of vehicles to be assembled in Canada by powertrain (e.g. BEV, PHEV) and vehicle (e.g. LDV, MHDV) type by the average price for each vehicle. More information on vehicle assembly projections and average battery capacity are available in Appendix II and Appendix III.

Furthermore, to estimate the demand for battery minerals and materials, the Trillium Network model assumes a certain market share for each battery chemistry by 2030 based on recent projections by Morgan Stanley.[32] The battery chemistries considered in this report are lithium nickel manganese cobalt (NMC), lithium nickel cobalt aluminum (NCA), lithium iron phosphate (LFP), and lithium manganese oxide (LMO). The assumed market shares are provided in Table 3.1. Note that EV battery chemistries are dynamic and closely related to the global supply of battery minerals and rates of EV adoption. Also note that to estimate the economic output related to cell and module manufacturing and pack assembly, we assume that only NMC-622 (a specific version of NMC) type batteries are manufactured in Canada.

Table 3.1 - Battery Chemistry Market Shares Assumptions for 2030

NMC	NCA	LFP	LMO
45%	5%	30%	20%

When evaluating the results of this study, it is important to consider the general limitations of input-output-based analysis. These limitations are described effectively in a document compiled by the Northwest Territories Bureau of Statistics.[33]

To estimate capital expenditure requirements corresponding to the economic output estimated at each node with the exceptions of mineral exploration, the Trillium Network model uses publicly-available information on specific projects detailed in Appendix III. When this information was not available, an average capital expenditure factor was calculated based on the requirements of similar projects (see Appendix III). Capital expenditures related to mineral exploration activities were estimated based on the mining node output using data related to the

[32] Morgan Stanley (2021), 'The New Oil: Investment Implications of the Global Battery Economy', Exhibit 39.

[33] Northwest Territories Bureau of Statistics (2006) 'NWT Input-Output Model: An Overview', https://www.statsnwt.ca/economy/multipliers/NWT%20IO%20Model-Overview.pdf

historical relationship between mining industry output and mineral exploration expenditures reported by Natural Resources Canada (see Appendix III).

To estimate government revenues, we rely on multipliers obtained from input-output tables, our direct employment estimates, average annual employee income statistics from Statistics Canada, federal and provincial tax brackets, and employment insurance premiums. The input-output tables provide multipliers for indirect government taxes on product purchases and production activities as well as employers' social contributions. To estimate the personal income taxes related to direct employment, we use average employee compensation under applicable NAICS codes we consider at each node (see Appendix II), federal personal income tax rates, and, for simplicity, Ontario personal income tax rates as a proxy for provincial incomes taxes.[34] Relevant assumptions and calculations are detailed in Appendix V. Corporate taxes and any royalties are excluded due to a myriad of difficulties in estimating them accurately.

3.2 - Scenario Design

In addition to a node-by-node analysis, the Trillium Network has designed four scenarios to quantify the potential economic impact of the EV battery supply chain in 2030. These scenarios were designed in consultation with Clean Energy Canada and the Canadian Battery Task Force.[35] Each scenario quantified total output, GDP, employment (FTEs), government revenues (including personal income taxes), and additional capital expenditures (primarily in plant and machinery) across the EV battery supply chain. As noted, our economic impact analysis does not quantify the potentially substantial infrastructure and workforce-related investments that may be required of governments. Table 3.2 provides an overview of each scenario. More detail on the assumptions that inform each scenario is available in Appendix III and throughout Sections 4 & 5.

[34] Ontario was chosen as the proxy because of its relatively low personal income tax rates when compared to Quebec and Manitoba. As such, our income tax contributions estimates are conservative.

[35] For more information on the Canadian Battery Task Force see: https://acceleratezev.ca/canadian-battery-task-force/#battmembers

Table 3.2 - Overview of Scenarios

Scenario	Features	Notes
1. Status Quo/Off-Target EV Adoption	● Assumes 25% of new LDV and 10% of new MHDV sales in Canada are BEV/PHEVs ● Assumes 16% of new LDV and 9% of new MHDV sales in the U.S. are BEV/PHEVs ● Includes output from realized and announced projects[36] and those likely to be realized by 2030[37]	● Baseline to measure Canada's minimum position in 2030 if no further investments are realized ● Baseline to develop Scenarios 2, 3, and 4 ● Increasingly unlikely
2. Status Quo/On-Target EV Adoption	● Assumes 25% of new LDV and 10% of new MHDV sales in Canada are BEV/PHEVs ● Assumes 16% of new LDV and 9% of new MHDV sales in the U.S. are BEV/PHEVs ● Output elsewhere in supply chain similar to Scenario 1	● Baseline to measure Canada's position in 2030 assuming higher EV adoption but no further supply chain investments
3. Continued Momentum	● Same level of EV adoption as previous scenario but increased output elsewhere in supply chain ● Increased output from mining and material manufacturing projects moderately likely to be operational in 2030[38]	● Assumes moderate investments and output increases across the supply chain ● Informed by optimism related to recent investments
4. Enhanced Contribution	● Assumes 90% of new LDV and 35% of new MHDV sales in Canada are BEV/PHEVs ● Assumes 50% of new LDV and 23% of new MHDV sales in the U.S. are BEV/PHEVs ● Increased output across nodes including mining and material manufacturing projects less likely to be operational in 2030[39]	● Extremely ambitious scenario and unlikely without serious and urgent government intervention ● Demonstrates potential economic impact of a comprehensive EV battery supply chain and ambitious market regulation of EVs to enhance supply (excluding R&D)

[36] Projects announced as of May 2022.

[37] This is based on Trillium Network's assessment of projects relevant to the EV battery supply chain in Canada. Some of the factors considered include but are not limited to: 1) acquisition of land or plant, 2) certainty of capital investment (e.g. committed or uncommitted), and 3) commencement or completion of major regulatory milestones (e.g. environmental and impact assessment processes, permitting), 4) past delays and issues with development, and 5) availability of necessary public infrastructure (e.g. roads, electricity). See Appendix III for details.

[38] See previous footnote.

[39] See previous footnote.

SECTION 4: QUANTIFYING ECONOMIC IMPACTS BY SCENARIOS

This report finds that building an EV battery supply chain in Canada could directly contribute between $5.7 billion and $24 billion to GDP annually by 2030, directly supporting between 18,486 and 81,357 jobs. These figures grow to annual contributions to GDP of between $15 billion and $59.4 billion and between 79,112 and 322,927 jobs when indirect and induced activities are included. Once realized, these activities would contribute between $2.7 billion and $11 billion annually in combined federal and provincial government revenues. These contributions, however, depend on how quickly and ambitiously Canadian governments act.

4.1 - Scenario 1: Status Quo + Off-Target EV Adoption

Scenario 1 illustrates a baseline case where one or a combination of exogenous factors such as recession, armed conflict, policy shifts, or supply chain disruptions cause EV sales across Canada and the United States to fall short of targets recently announced by governments. In this scenario, we assume that approximately 435,000 BEVs and PHEVs are assembled in Canada (with a combined battery capacity of 23 GWh) and 1.85 million BEVs and PHEVs are assembled in the United States (with a combined battery capacity of 101 GWh) in 2030. Our estimates for Canadian EV battery mineral mining, battery material production, EV battery component manufacturing, and battery cell production are based on the reported capacities of existing or announced investments that are likely to be realized by 2030. More information regarding these assumptions is available in Appendix III.

In short, Scenario 1 provides a baseline on which further EV battery supply chain investments can build. Table 4.1.1 illustrates the economic impact of a number of investments that are already secured and are likely to be realized by 2030 (and, with some exceptions, do not require further capital expenditures). It also shows the extent to which production capacity has been secured at different stages of the supply chain.

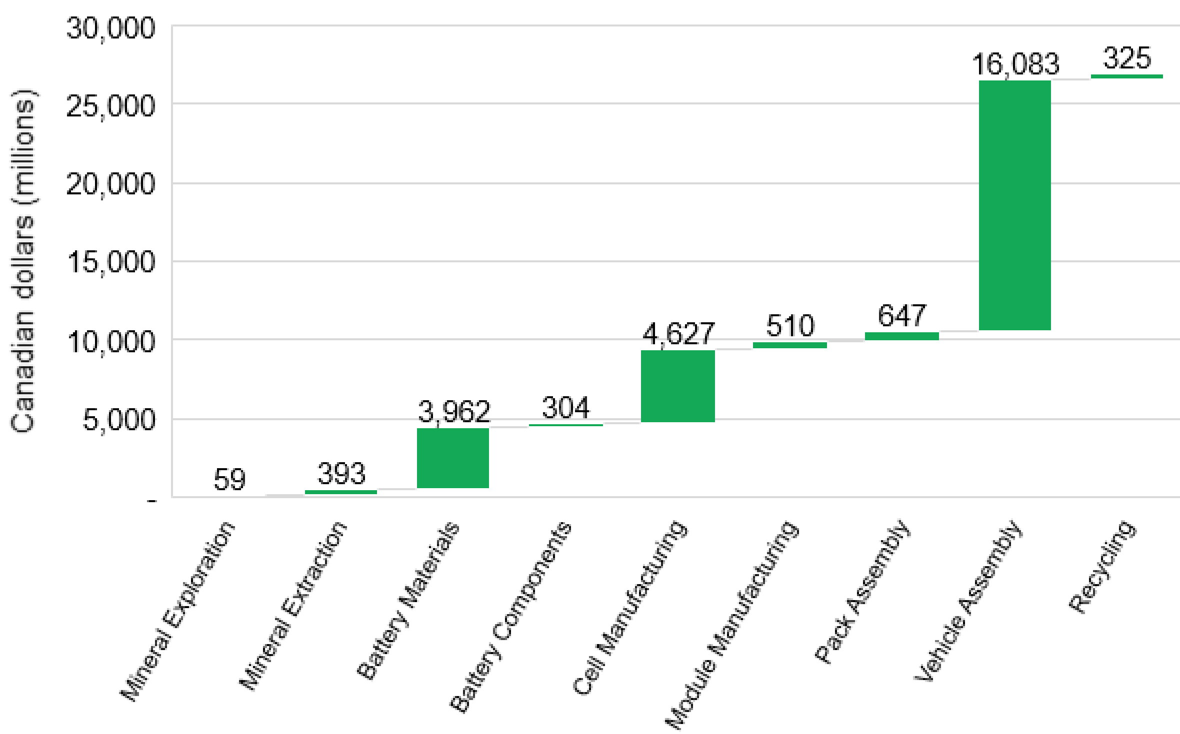
In Scenario 1, annual output across Canada's EV battery supply chain is approximately $27 billion (Figure 4.1.1) The majority of this output is associated with EV assembly across several LDV plants in Ontario and some MHDV manufacturing facilities in Québec and Manitoba. EV battery materials and battery cell manufacturing are responsible for the majority of the remainder. These activities are projected to directly contribute $5.7 billion to GDP annually, and $15 billion when indirect and induced activities are considered (Figure 4.1.2). Scenario 1 results in 18,486 persons employed directly and 79,112 persons employed as the result of direct, indirect, and induced activities across the EV battery supply chain (Figure 4.1.3). A majority of these jobs are associated directly or indirectly with EV assembly. Most of the remainder are associated with EV battery material and cell manufacturing.

To realize these economic impacts, approximately $5.2 billion in capital expenditures beyond those that have already been committed are necessary (Figure 4.1.4). The majority of these expenditures will be related to upgrading and refurbishing EV assembly facilities in the latter part of the decade. These figures do not include infrastructure or workforce development, or other government-related investments necessary to support the EV battery supply chain. Once realized, these activities will contribute $2.7 billion annually in combined federal and provincial government revenues, provincial and federal combined (Figure 4.1.5).

Table 4.1.1 - Economic Impact (Summary), Scenario 1

Node	**Output ($ millions)**	**GDP ($ millions)**	**Employment**	**Government Revenues ($ millions)**	**Capital Expenditures ($ millions)**[40]
Mineral Exploration	$59	$66	524	$18	N/A
Mining	$393	$415	2,238	$69	N/A
Battery Materials	$3,962	$2,682	14,964	$425	N/A
Battery Components	$304	$207	1,712	$55	N/A
Cell Manufacturing	$4,627	$4,099	12,203	$424	N/A
Module Manufacturing	$510	$379	586	$67	$214
Pack Assembly	$647	$481	536	$83	$244
Vehicle Assembly	$16,083	$6,429	45,127	$1,507	$4,735
Recycling	$325	$229	1,149	$37	N/A
Total	$26,910	$14,986	79,112	$2,685	$5,193

Figure 4.1.1 - Total EV Battery Supply Chain Output, Scenario 1



40 See Methodology for a definition of capital expenditures.

Figure 4.1.2 - EV Battery Supply Chain Contributions to GDP, Scenario 1

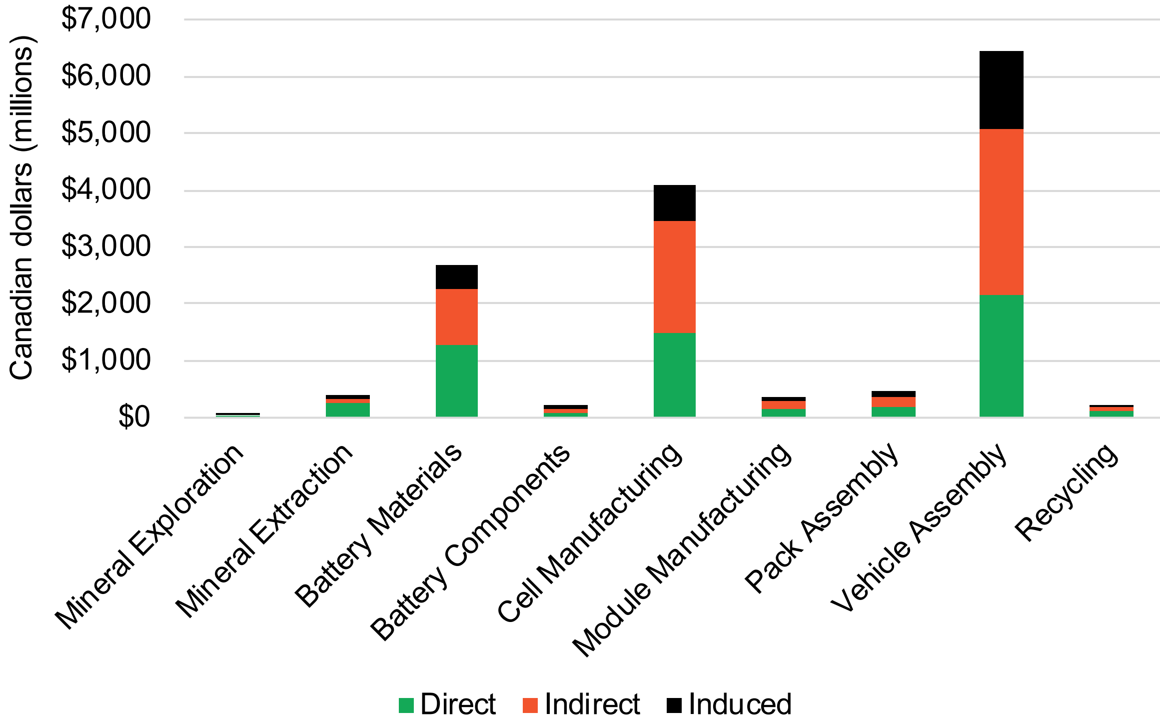


Figure 4.1.3 - EV Battery Supply Chain Employment, Scenario 1

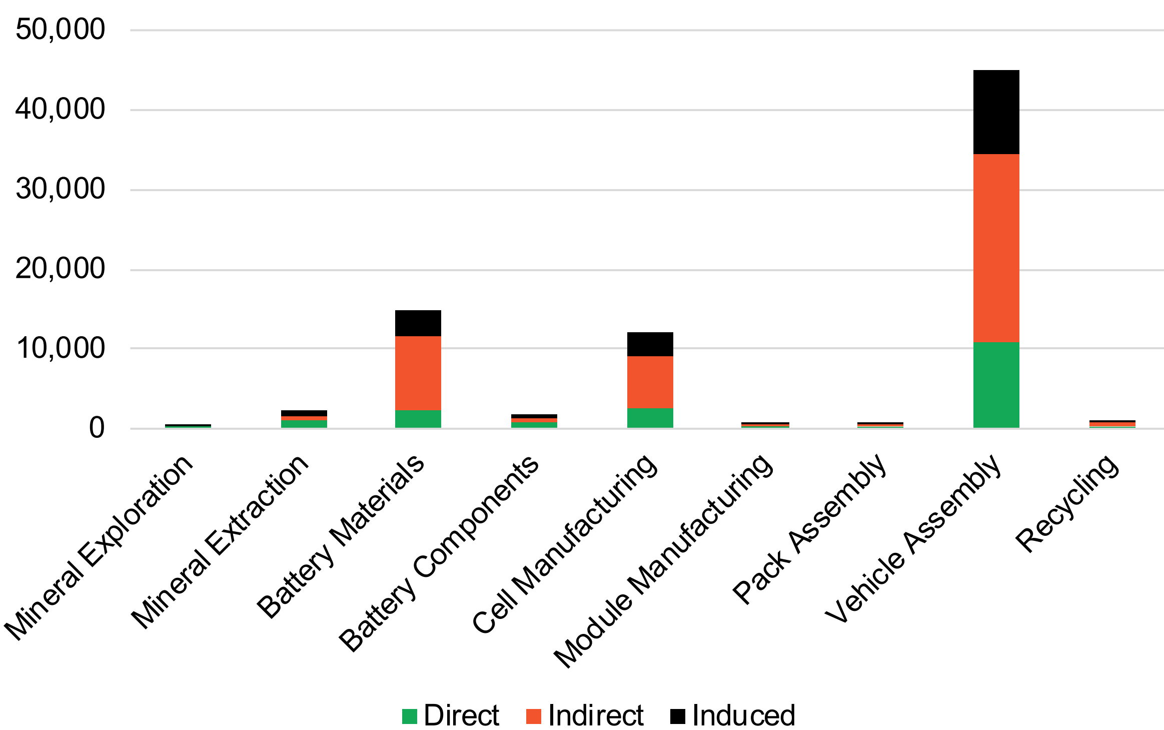


Figure 4.1.4 - Additional Capital Expenditures, Scenario 1

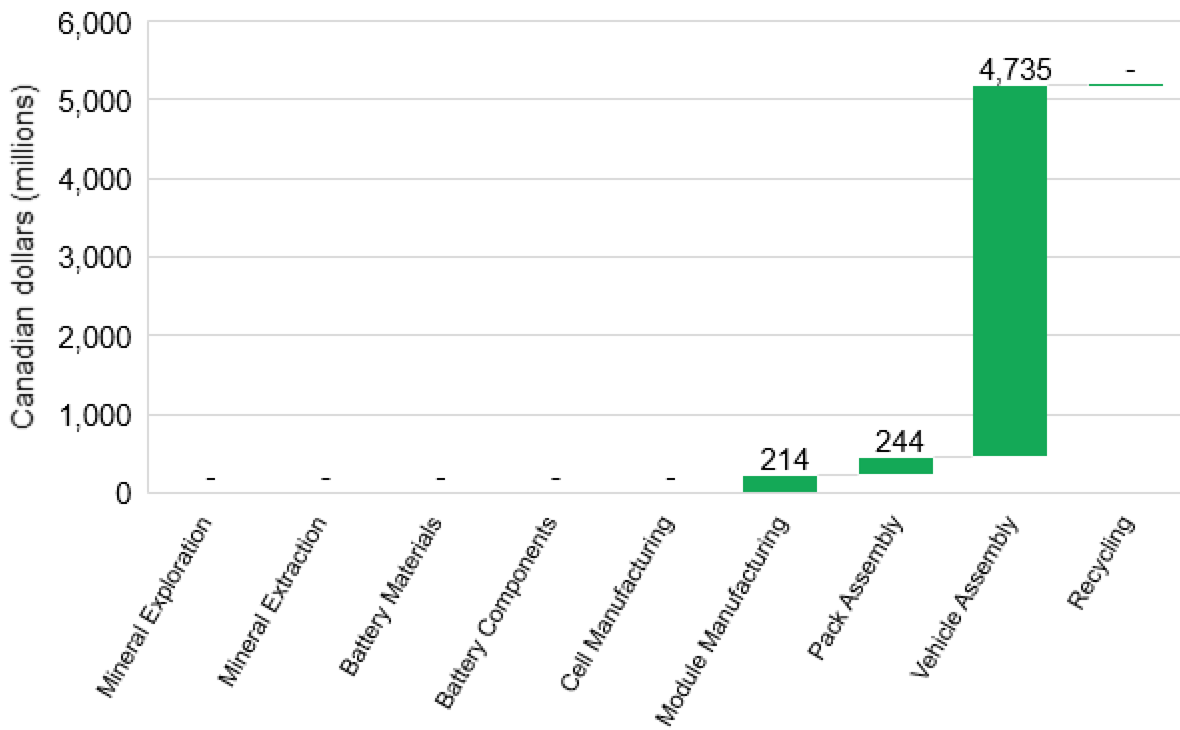
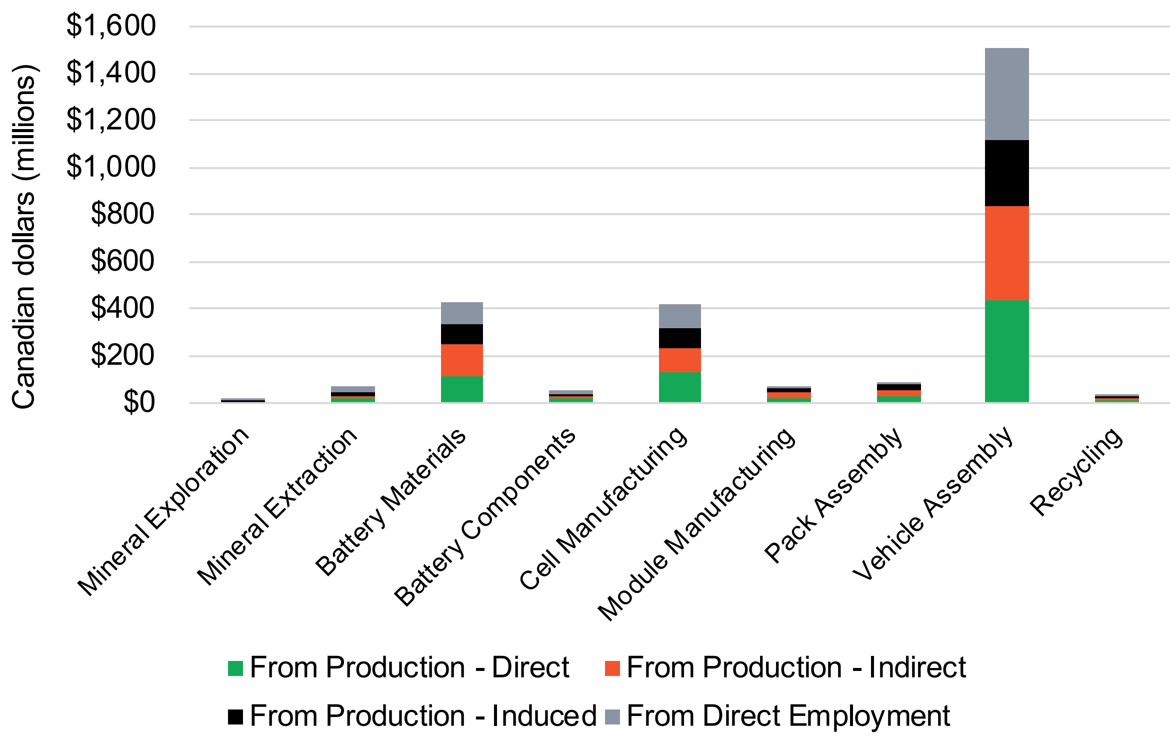


Figure 4.1.5 - Annual Government Revenues, Scenario 1



4.2 - Scenario 2: Status Quo + On-Target EV Adoption

The assumptions in Scenario 2 are similar to those in Scenario 1, with three exceptions. First, Canada will meet recently-announced government EV sales targets of 60 per cent for LDVs and 35 per cent for MHDVs by 2030. Second, EV adoption in the United States will reach 33 per cent for LDVs and 16 per cent for MHDVs. These targets are used alongside production-to-sale ratios [41] detailed in Appendix III to estimate the number of EVs that will be assembled in Canada. This will correspond to the production of one million EVs in Canada and 3.8 million EVs in the United States in 2030. Third, EV battery module manufacturing and pack assembly output will increase in proportion to EV production. In short, this scenario illustrates Canada's position with more investment in EV assembly but no further investment beyond that described in Scenario 1 in other parts of the supply chain. The economic impact of Scenario 2 is summarized in Table 4.2.1.

Table 4.2.1 - Economic Impact (Summary), Scenario 2

Node	Output ($ millions)	GDP ($ millions)	Employment	Government Revenues ($ millions)	Capital Expenditures ($ millions)
Mineral Exploration	$59	$66	524	$18	N/A
Mining	$393	$415	2,238	$69	N/A
Battery Materials	$3,962	$2,682	14,964	$425	N/A
Battery Components	$304	$207	1,712	$56	N/A
Cell Manufacturing	$4,627	$4,099	12,203	$424	N/A
Module Manufacturing	$1,202	$893	914	$153	$375
Pack Assembly	$1,470	$1,092	835	$184	$438
Vehicle Assembly	$39,088	$15,691	110,401	$3,683	$11,386
Recycling	$325	$229	1,175	$37	N/A
Total	**$51,429**	**$25,373**	**144,970**	**$5,049**	**$12,200**

In Scenario 2, total economic output across Canada's EV battery supply chain is approximately $51.4 billion (Figure 4.2.1). More than three-quarters of this output is associated with EV assembly. An additional 17 per cent of output is associated with EV battery material and cell manufacturing. Taken together, these activities contribute $9.3 billion directly to GDP annually and $25.4 billion when indirect and induced contributions are considered (Figure 4.2.2). Scenario 2 results in 34,756 persons employed directly and 144,970 persons employed when direct, indirect, and induced activities are included (Figure 4.2.3).

To realize these economic impacts, approximately $12.2 billion in capital expenditures beyond those that have already been committed are required (Figure 4.2.4). Like Scenario 1, a large majority of these expenditures are related to upgrading and retooling vehicle assembly facilities.

[41] Production-to-sales ratio is defined as the number of vehicles assembled divided by the number of vehicles sold in the same country in a given year.

In total, these activities are projected to provide more than $5 billion annually in government revenue (Figure 4.2.5).

Figure 4.2.1 - Total EV Battery Supply Chain Output, Scenario 2

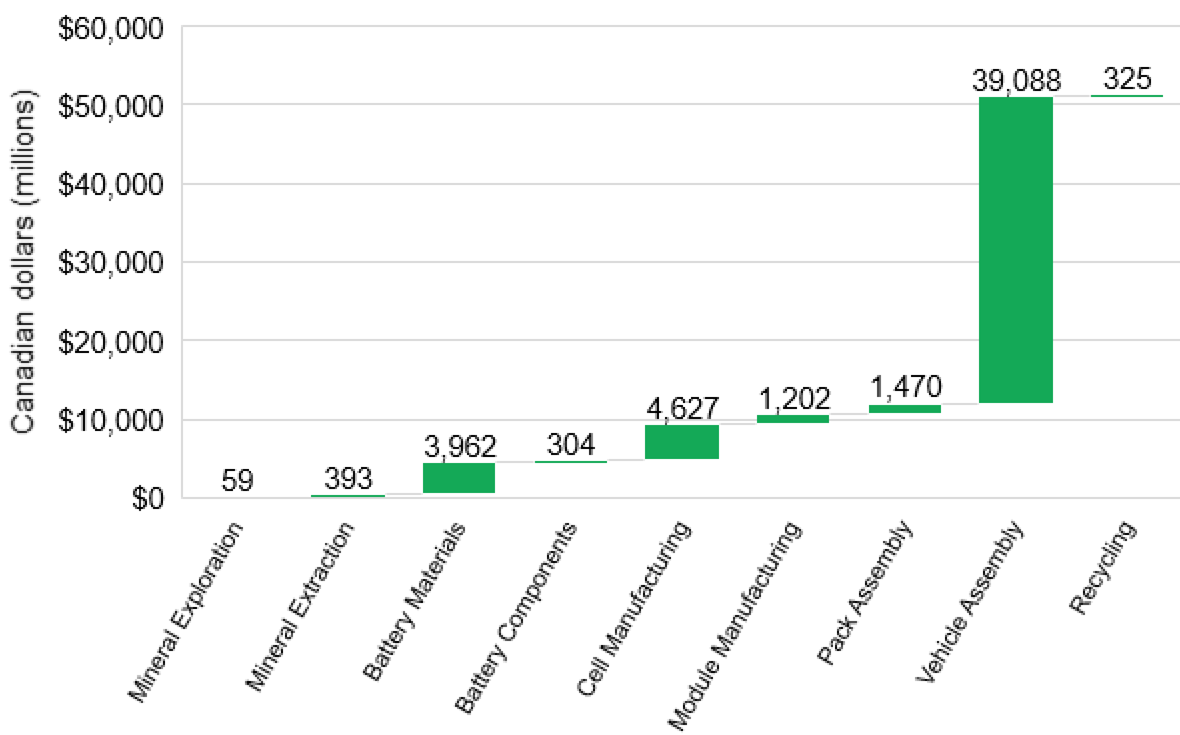


Figure 4.2.2 - EV Battery Supply Chain Contributions to GDP, Scenario 2

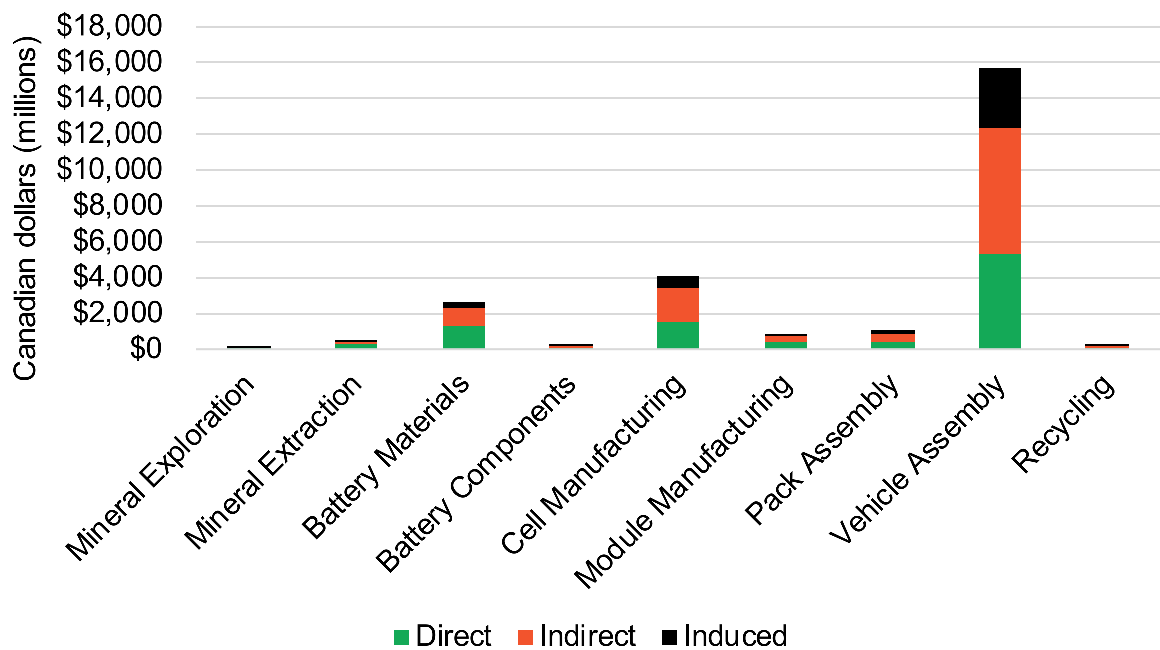


Figure 4.2.3 - EV Battery Supply Chain Employment, Scenario 2

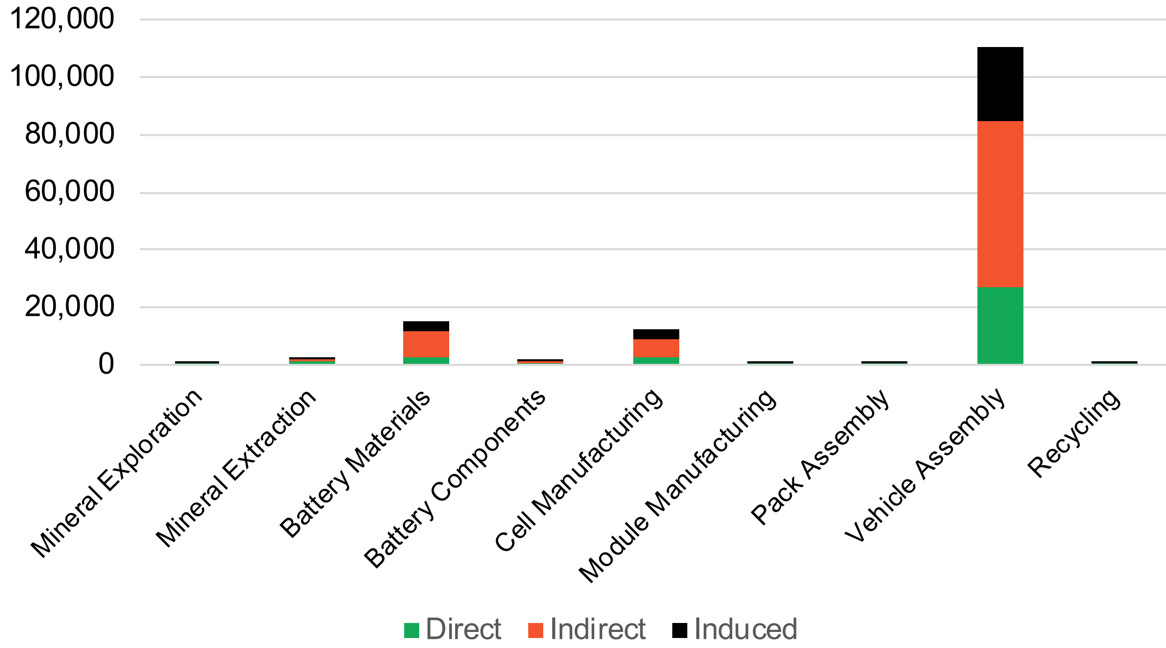


Figure 4.2.4 - Additional Capital Expenditures, Scenario 2

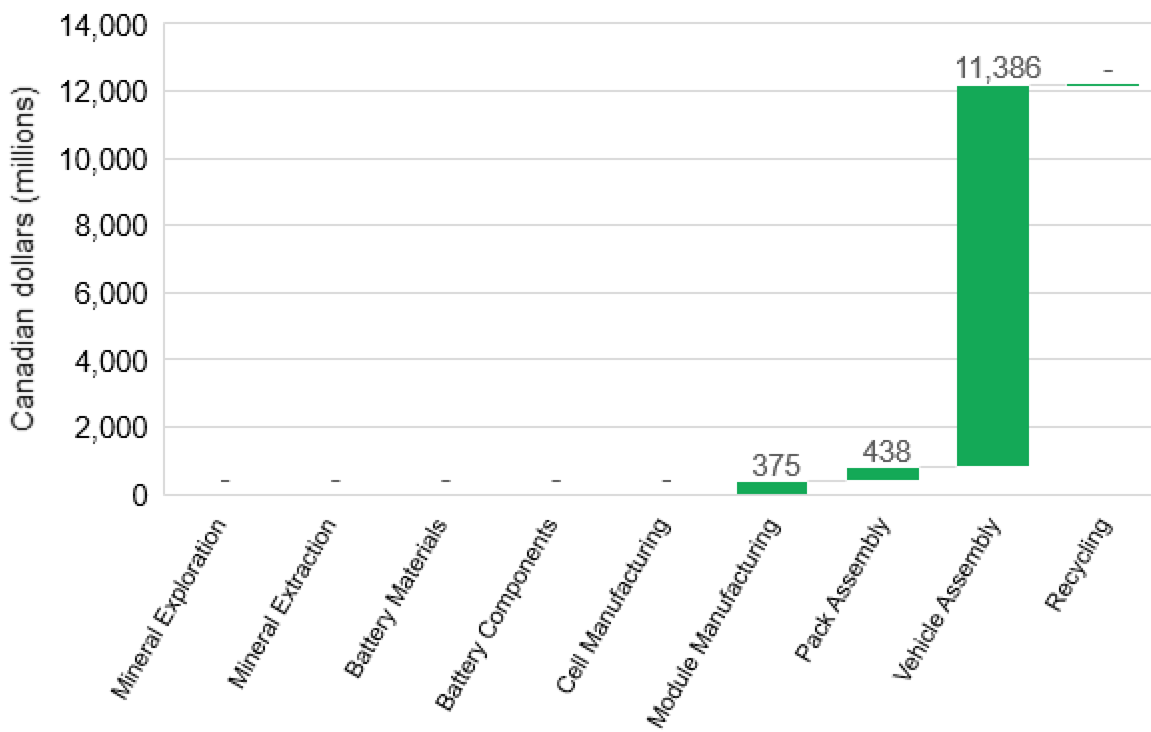
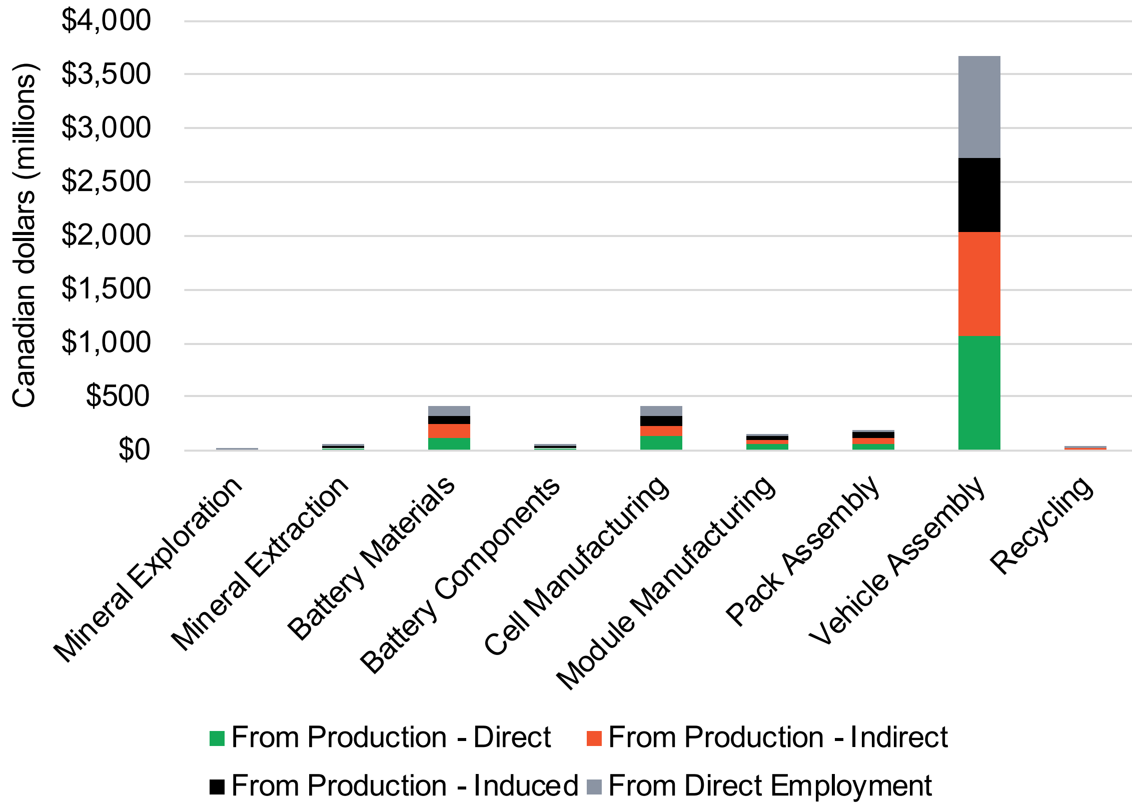


Figure 4.2.5 - Annual Government Revenues, Scenario 2



4.3 - Scenario 3: Continued Momentum

Scenario 3 is inspired by the optimism surrounding the flurry of recent investments across Canada's EV battery supply chain. It features similar EV assembly assumptions as Scenario 2 but includes more production in other supply chain nodes. It assumes that several mining projects in the early stages of development will come online by 2030, leading to substantial increases in lithium, nickel, and phosphate rock mining and moderate increases in cobalt and graphite mining. It assumes that the production of battery materials such as lithium carbonate, lithium hydroxide, nickel sulphate, and electrolyte will increase beyond those investments that have already been announced. It assumes cathode active material (CAM) production will double when compared to Scenarios 1 and 2 and that anode material production will increase. Finally, we assume a small increase in cobalt sulphate production.

In addition to further investments in mining and battery materials manufacturing, Scenario 3 assumes Canada will attract another full-scale EV battery cell manufacturing facility, leading to a total annual production of 90 GWh across two plants. It also assumes a North American market share of 6.3 per cent of EV battery component production and that additional recycling facilities will come online servicing the entire Canadian market (shredding and chemical conversion) and 18 per cent of the U.S. market (chemical conversion only). The economic impact of Scenario 3 is summarized in Table 4.3.1.

In Scenario 3, total annual output across Canada's EV battery supply chain is approximately $65 billion (Figure 4.3.1). While a large proportion of this output continues to be associated with EV assembly, the economic contributions of battery material and cell manufacturing and mining-related investments are considerably higher when compared to Scenarios 1 and 2. When combined, these activities are projected to contribute $14.1 billion to annual GDP directly and $36 billion when indirect and induced contributions are considered (Figure 4.3.2). Scenario 3 also results in a total of 198,669 persons employed as the result of direct, indirect, and induced activities (Figure 4.3.3). While a slight majority of these jobs are associated with EV assembly, a larger proportion is associated with EV battery minerals, materials, and cell manufacturing when compared to Scenarios 1 and 2.

Realizing the opportunities associated with Scenario 3 will require substantial capital expenditures when compared to Scenarios 1 and 2. In this case, we estimate these expenditures to be approximately $30 billion (Figure 4.3.4). While vehicle assembly investments continue to be the largest, capital expenditures of more than $4 billion are necessary to bring additional EV battery mineral, material, and battery cell activities online. In total, these activities are projected to provide more than $6.7 billion in annual government revenue (Figure 4.3.5).

Table 4.3.1 - Economic Impact (Summary), Scenario 3

Node	**Output ($ millions)**	**GDP ($ millions)**	**Employment**	**Government Revenues ($ millions)**	**Capital Expenditures ($ millions)**
Mineral Exploration	$277	$309	2,464	$83	$94
Mining	$1,849	$1,811	8,880	$315	$5,565
Battery Materials	$10,453	$7,142	40,870	$1,159	$4,513
Battery Components	$1,780	$1,250	10,226	$325	$1,335
Cell Manufacturing	$8,408	$7,449	22,178	$771	$4,627
Module Manufacturing	$1,202	$893	914	$153	$375
Pack Assembly	$1,470	$1,092	835	$184	$438
Vehicle Assembly	$39,088	$15,691	110,401	$3,683	$11,386
Recycling	$449	$336	1,899	$58	$1,631
Total	**$64,977**	**$35,974**	**198,669**	**$6,730**	**$29,965**

Figure 4.3.1 - Total EV Battery Supply Chain Output, Scenario 3

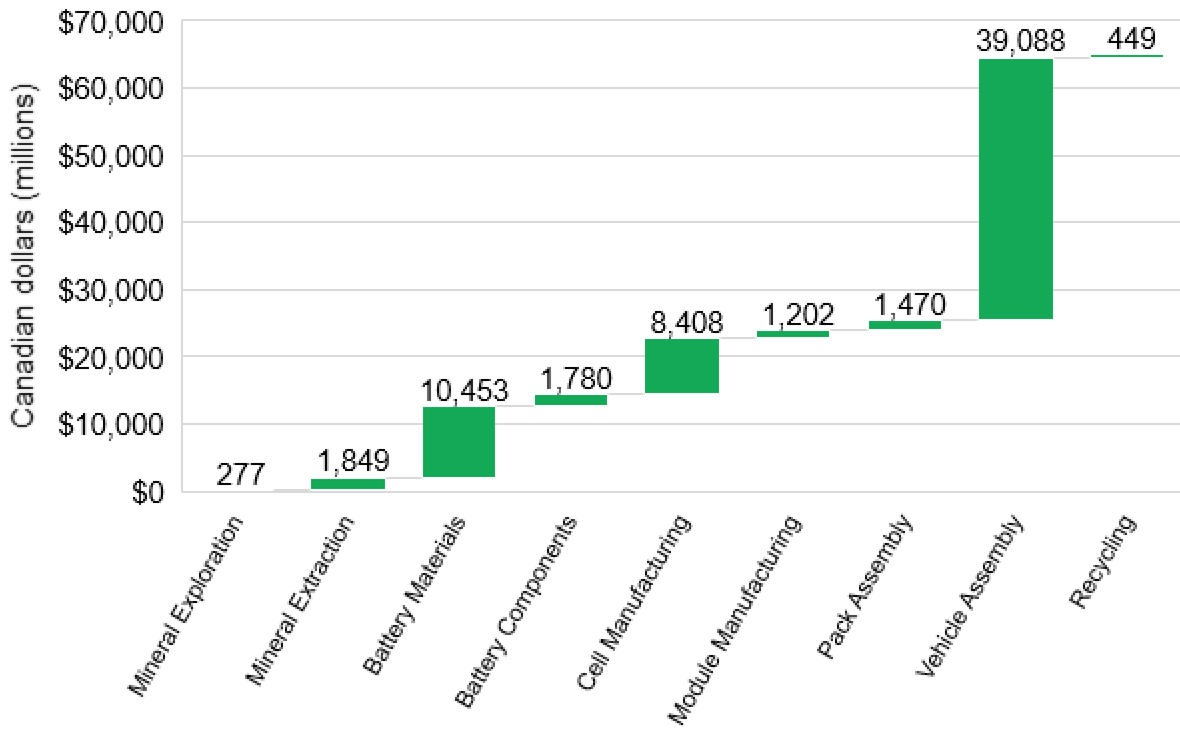


Figure 4.3.2 - EV Battery Supply Chain Contributions to GDP, Scenario 3

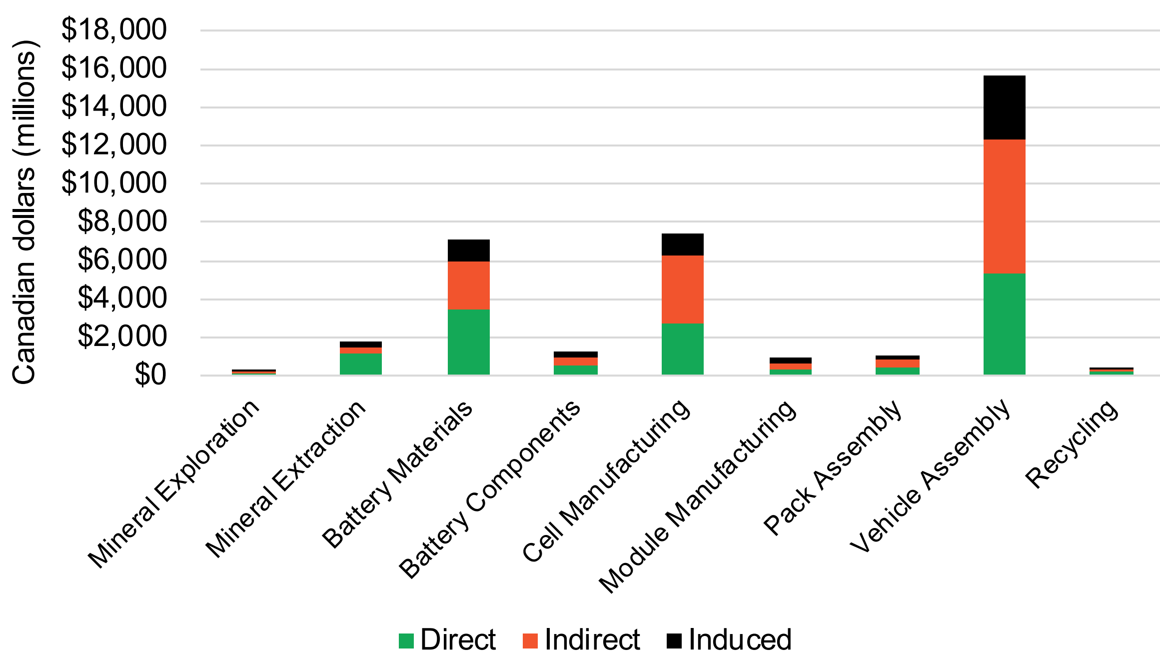


Figure 4.3.3 - EV Battery Supply Chain Employment, Scenario 3

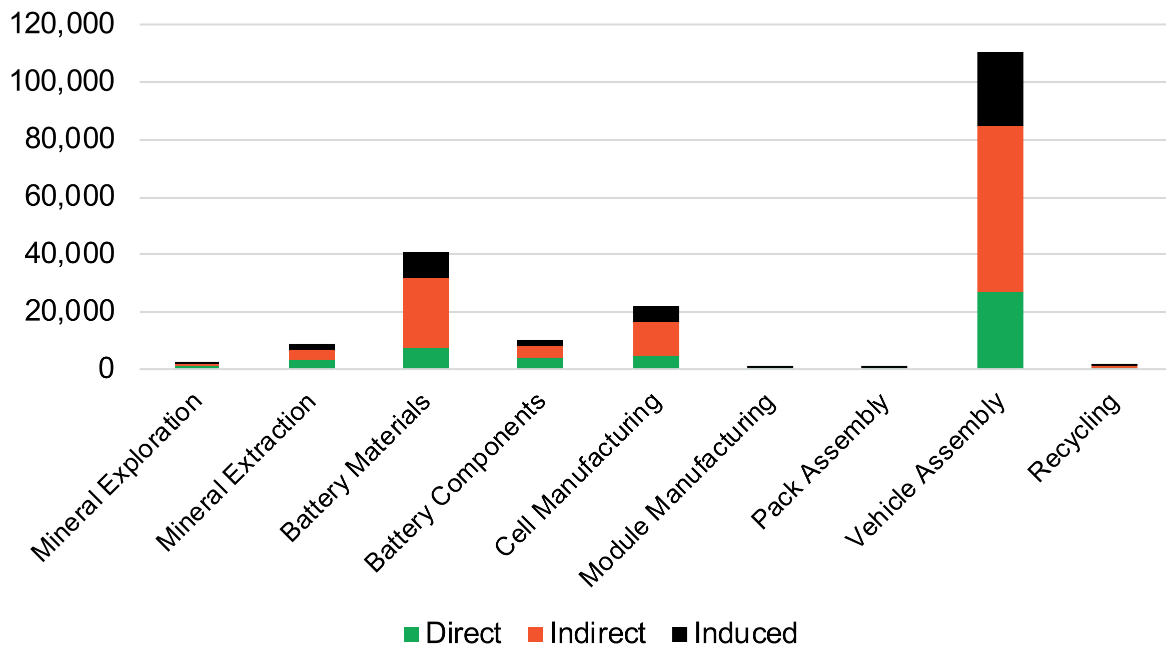


Figure 4.3.4 - Additional Capital Expenditures, Scenario 3

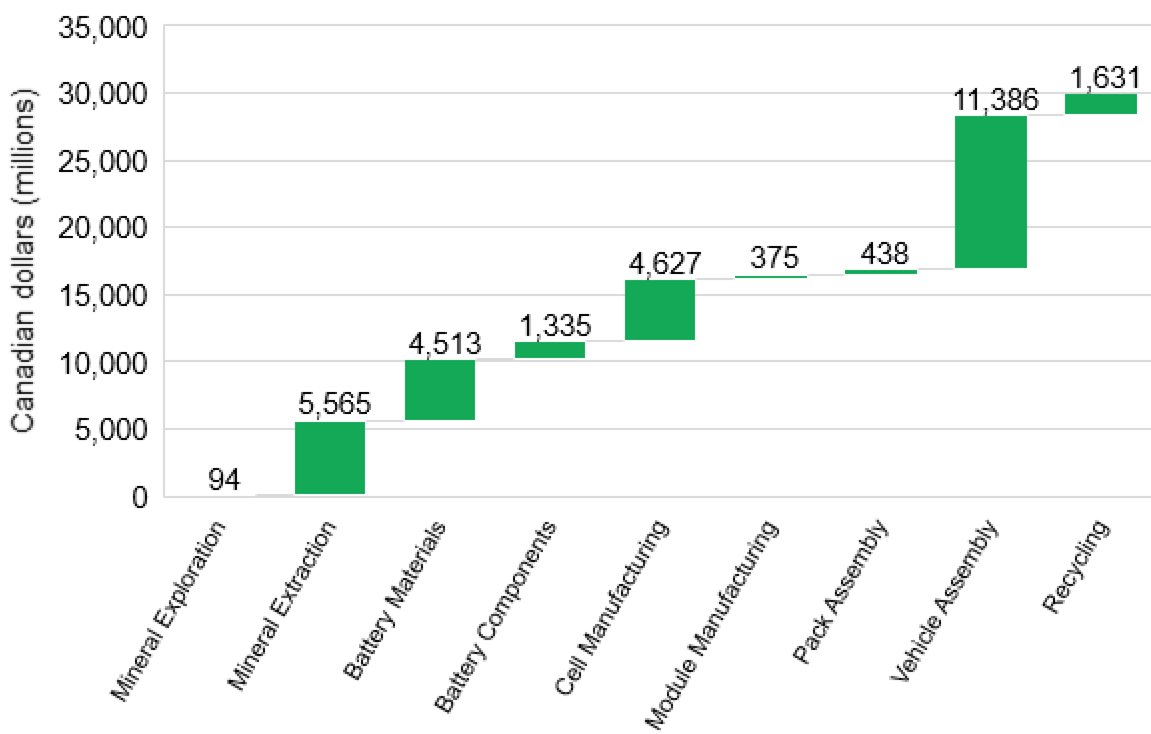
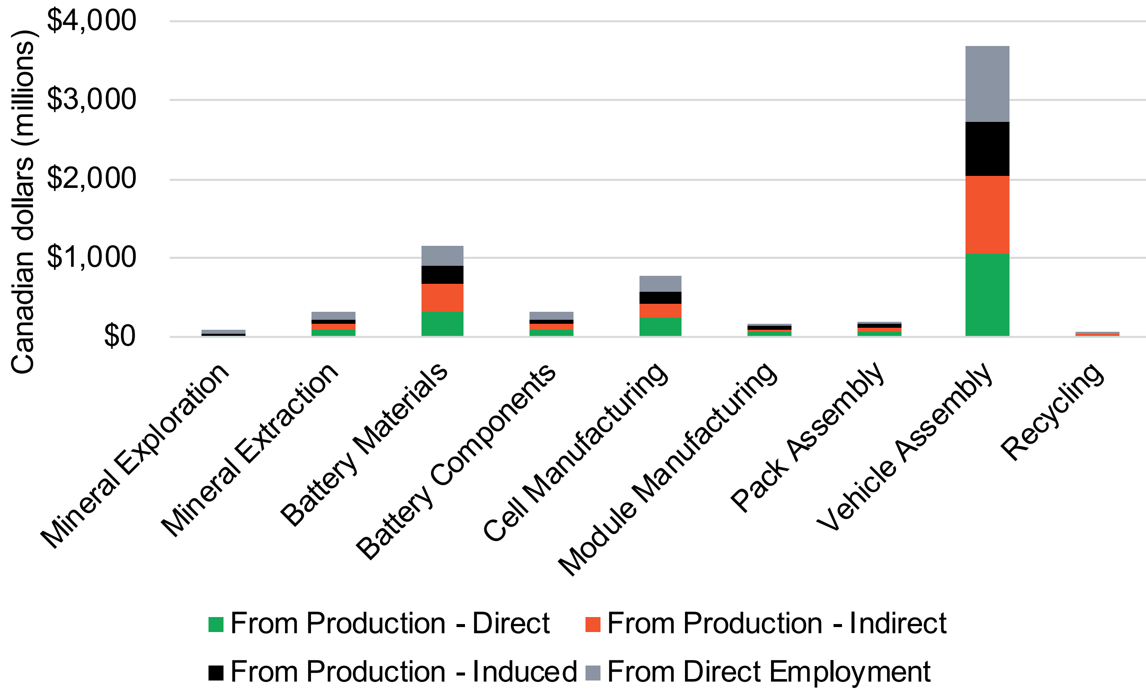


Figure 4.3.5 - Annual Government Revenues, Scenario 3



4.4 - Scenario 4: Enhanced Contribution

Scenario 4 builds on Scenario 3 by incorporating additional production capacities across the EV battery supply chain. It includes increased EV production in Canada (1.5 million units annually) and the United States (5.8 million units annually). This scenario assumes several mining projects not considered in previous scenarios will come online by 2030 as the result of expedited development and construction timelines. This, in turn, will lead to substantial increases in lithium, nickel, cobalt, and manganese production. Similarly, Scenario 4 assumes that the production of lithium carbonate, nickel sulphate, manganese sulphate, phosphate, and electrolyte will increase. These are, with the exception of electrolyte, based on known projects at early stages of development and approval. Furthermore, Scenario 4 assumes that two additional EV battery cell manufacturing facilities will come online: Britishvolt (60 GWh) and StromVolt (10 GWh), leading to a total of 160 GWh of annual production across four plants. Finally, we assume a North American market share of 12.5 per cent of EV battery components [42] and 25 per cent of the U.S. Market share for battery recycling. The economic impact of Scenario 4 is summarized in Table 4.4.1.

[42] With the exception of negative current collector (copper foil). See Appendix IV for details.

Table 4.4.1 - Economic Impact (Summary), Scenario 4

Node	Output ($ millions)	GDP ($ millions)	Employment	Government Revenues ($ millions)	Capital Expenditures ($ millions)
Mineral Exploration	$717	$798	6,369	$214	$242
Mining	$4,781	$4,546	21,174	$803	$14,854
Battery Materials	$16,523	$11,282	64,428	$1,827	$10,199
Battery Components	$4,156	$2,869	23,635	$756	$3,117
Cell Manufacturing	$15,020	$13,307	39,617	$1,377	$7,351
Module Manufacturing	$1,812	$1,346	1,142	$228	$477
Pack Assembly	$2,163	$1,608	1,041	$269	$566
Vehicle Assembly	$57,855	$23,121	162,269	$5,417	$17,044
Recycling	$788	$584	3,254	$100	$4,525
Total	**$103,816**	**$59,462**	**322,927**	**$10,991**	**$58,376**

In Scenario 4, total annual output across Canada's EV battery supply chain is more than $103 billion (Figure 4.4.1). Vehicle assembly accounts for more than half of this output, while battery material and cell manufacturing each account for more than $15 billion of output. Mineral-related output exceeds $5 billion, EV battery component output exceeds $4 billion, and output related to battery module manufacturing and battery pack assembly each exceeds $1.5 billion.

In this scenario, direct contributions to GDP are projected to be in excess of $24 billion (Figure 4.4.2). These contributions exceed $59 billion when we include GDP associated with indirect and induced activities. Scenario 4 also results in the direct employment of 81,357 persons across the supply chain and total employment of nearly 333,000 persons when indirect and induced activities are considered (Figure 4.4.3). It is in this scenario that the economic contributions of the EV battery supply chain begin to exceed those of an ICEV-focused Canadian automotive industry that manufactures more than 2 million vehicles annually.

Realizing the opportunities outlined in Scenario 4 requires capital expenditures in excess of $58.3 billion (Figure 4.4.4). More than $17 billion of these expenditures are related to vehicle assembly and nearly $14.9 billion are related to mining. Investments in the billions of dollars are also necessary to realize opportunities in other nodes of the EV battery supply chain. These investments in a comprehensive EV battery supply chain will, however, result in annual government revenues of nearly $11 billion (Figure 4.4.5). While about half of these revenues are related to EV assembly, several nodes are projected to contribute more than $1 billion annually to government revenues.

Figure 4.4.1 - Total EV Battery Supply Chain Output, Scenario 4

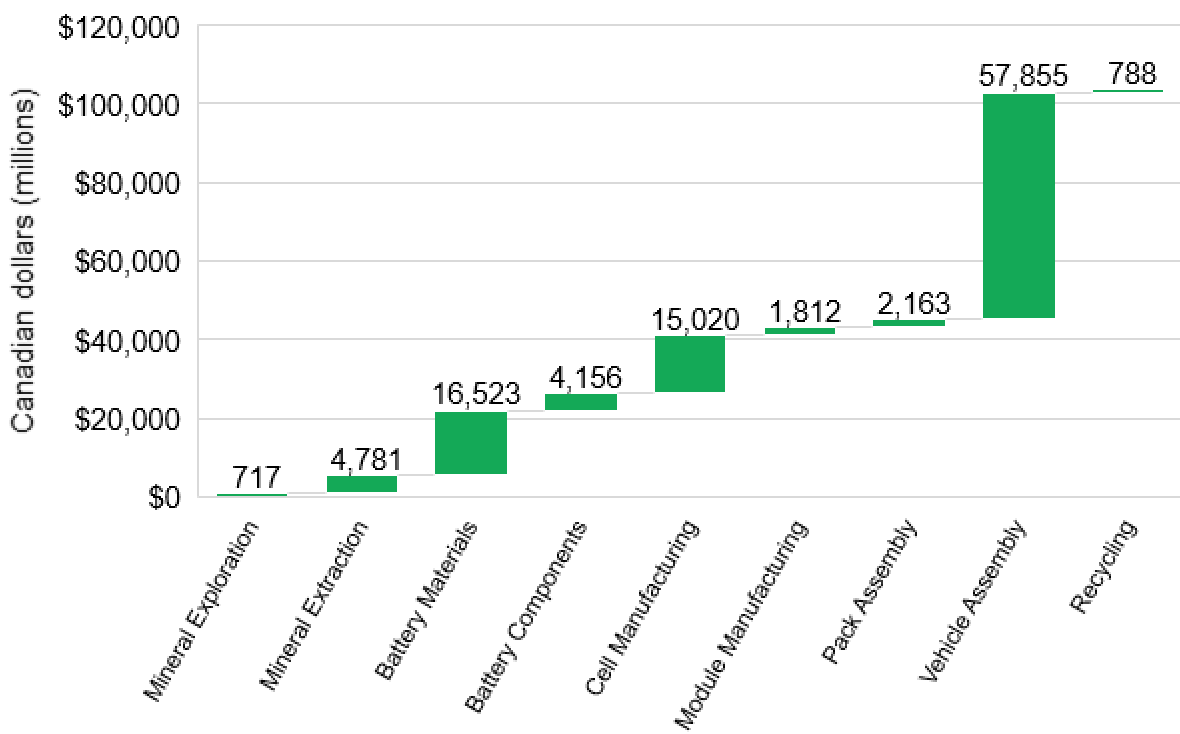


Figure 4.4.2 - EV Battery Supply Chain Contributions to GDP, Scenario 4

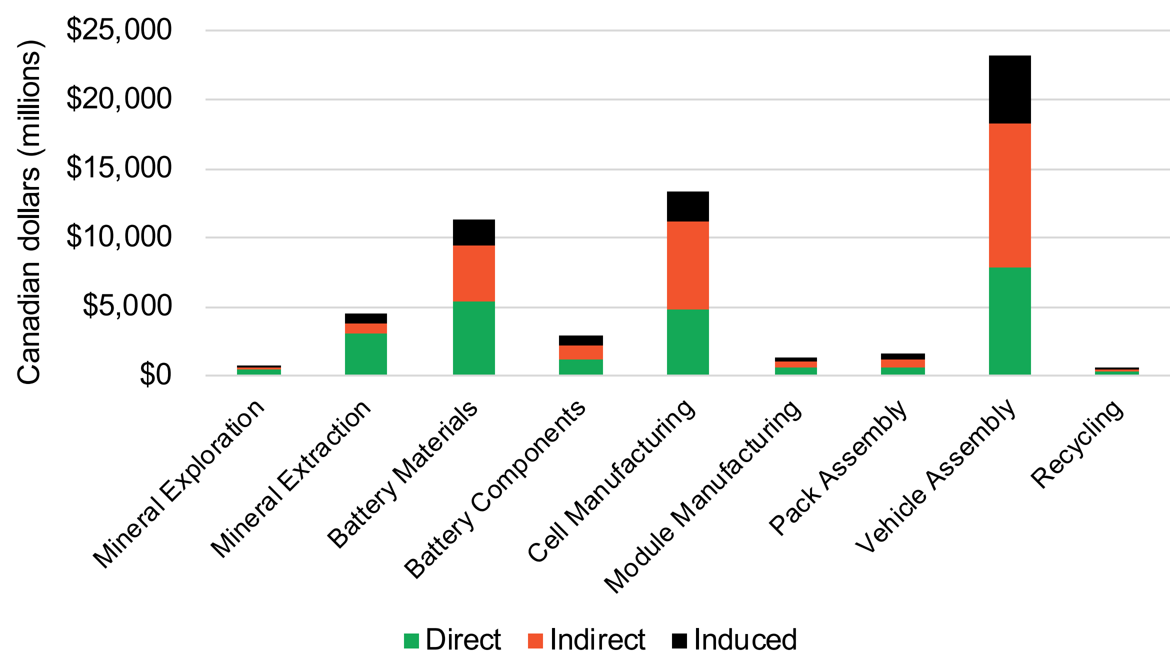


Figure 4.4.3 - EV Battery Supply Chain Employment, Scenario 4

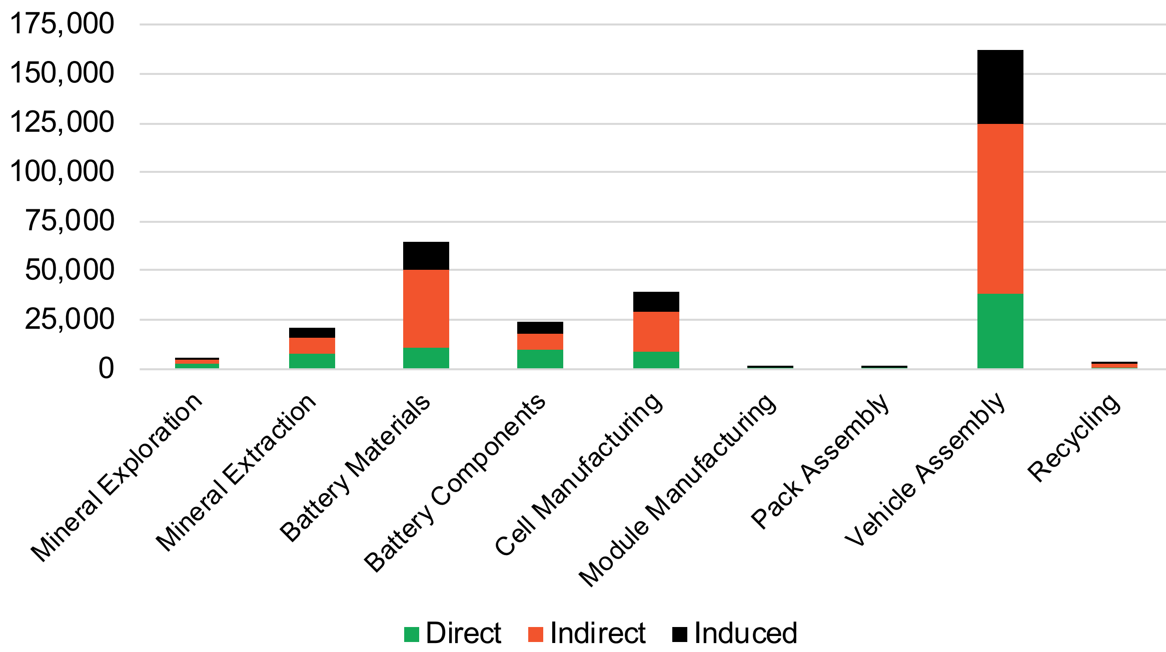


Figure 4.4.4 - Additional Capital Expenditures, Scenario 4

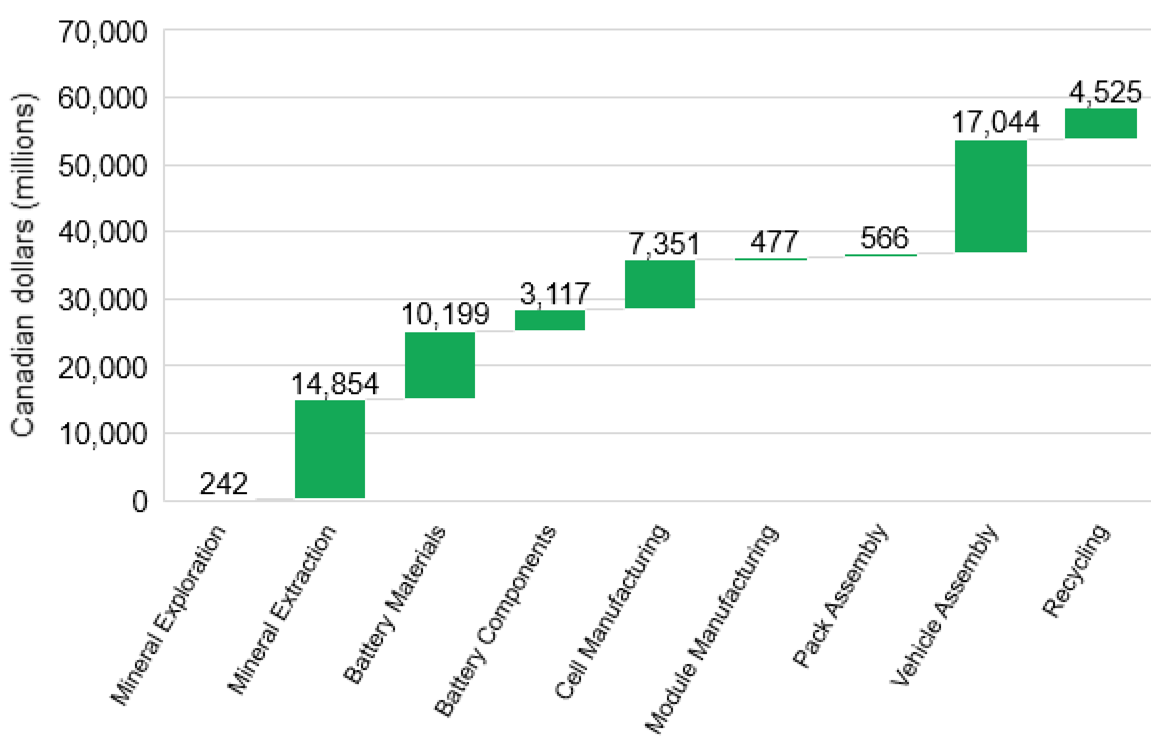
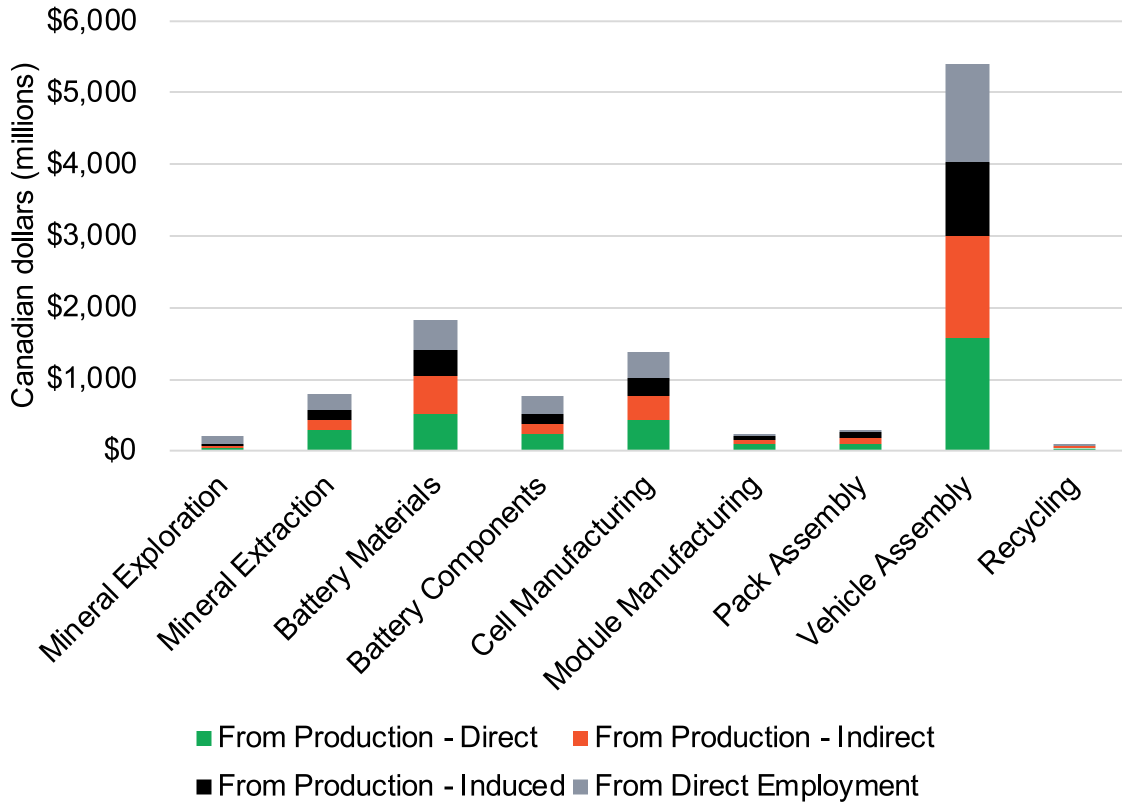


Figure 4.4.5 - Annual Government Revenues, Scenario 4



SECTION 5: QUANTIFYING ECONOMIC IMPACTS BY EV BATTERY SUPPLY CHAIN NODE

This section reviews each of the nine nodes in the EV battery supply chain as identified by Clean Energy Canada. In addition to providing background information about each node and a summary of Canada's current position, the analysis quantifies the range of potential economic benefits based on the scenarios described in the previous section.

5.1 - Mineral Exploration

5.1.1 - Overview

Mineral exploration refers to activities that lead to the discovery and development of mineral deposits that may become future mines. These activities are important in ensuring the long-term viability of Canada's mining industry. Exploration often takes place in remote and northerly regions and can lead to significant investments for communities in those areas. These activities are highly sensitive to market conditions and commodity prices fluctuations.[43]

Two categories of companies are involved in mineral exploration: junior and senior. Junior miners, of which Canada is home to a large number, generally have little operating revenue and rely on equity financing. They are characterized by their small size and specialization in riskier early-stage exploration activities. Their reliance on equity financing makes them sensitive to adverse market conditions.[44] Senior mining companies, which build and operate mines, are more likely to be involved in later stages of exploration and in transitioning a mineral claim or deposit into an operating mine. Junior and senior mining companies account for roughly equal amounts of spending on mineral exploration in Canada.[45]

Most mineral exploration work is carried out by specialized contractors that support junior and senior mining companies. They provide services such as drilling, testing, and site evaluation. Projects vary considerably based on geological and topographic conditions. Costs also vary based on the location of the project relative to infrastructure. Unlike operating mines or manufacturing facilities, exploration requires little fixed capital investment.

5.1.2 - Canada's Current Position

Mineral exploration is captured alongside a series of other mining support activities in Statistics Canada datasets under NAICS codes 213117 and 213119 (or through the amalgamated

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[43] Natural Resources Canada (2021) 'Canadian Mineral Exploration Information Bulletin, https://www.nrcan.gc.ca/maps-tools-and-publications/publications/minerals-mining-publications/canadian-mineral-exploration/17762

[44] Natural Resources Canada (2021) 'Canadian Mineral Exploration Information Bulletin'', https://www.nrcan.gc.ca/maps-tools-and-publications/publications/minerals-mining-publications/canadian-mineral-exploration/17762

[45] Natural Resources Canada (2021) 'Canadian Mineral Exploration Information Bulletin', https://www.nrcan.gc.ca/maps-tools-and-publications/publications/minerals-mining-publications/canadian-mineral-exploration/17762

industry code BS21311B). In 2019, these activities generated $5.6 billion in output,[46] directly contributed $3.2 billion to GDP,[47] and directly employed nearly 26,000 people.[48] However, the majority of the mineral exploration industry is focused on precious metals (e.g. gold) and only a small proportion of those activities (approximately three per cent) were related to EV battery minerals such as lithium, graphite, cobalt, and manganese in 2021 (Table 5.1.1).[49]

Table 5.1.1 - Canadian Mineral Exploration Expenditures, 2021

Mineral Commodity	**Expenditures**
Precious Metals	$2B
Base Metals	$502M
Uranium	$95M
Other Metals	$87M
Coal	$75M
Non-Metals (i.e. Potash)	$41M
Diamonds	~$39M
Iron Ore	~$23M

As demand for EV battery minerals increases in the future, mineral exploration activities will play an important role in identifying and developing new opportunities for Canada's mining industry. While there has been considerable recent interest among governments and the private sector, market conditions and commodity price fluctuations will prove critical in determining whether these activities will grow and lead to operating mines.

Our research identified 46 companies currently involved in 70 early-stage mineral exploration projects that focused on EV battery minerals. Of these projects, 26 focused on lithium, 15 on nickel, 15 on copper, six on cobalt, six on graphite, and two on manganese. Company documents referred explicitly to battery-related opportunities in 45 of the 70 projects. In addition to these projects, we identified several in later stages of exploration or development. Those that have the potential to be online in 2030 are included in our analysis of the mining industry.

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[46] Statistics Canada (2019) 'Symmetric Input Output Tables', obtained by the Trillium Network for Advanced Manufacturing through a custom data order.
[47] Trillium Network's calculation based on industry output and GDP multipliers obtained from the Statistics Canada 2019 Symmetric Input Output Tables (see above).
[48] Statistics Canada Table 36-10-0480-01 (formerly CANSIM 383-0033)
[49] Information for Table 3.1.1 is derived from: Natural Resources Canada (2021) 'Canadian Mineral Exploration Information Bulletin', https://www.nrcan.gc.ca/maps-tools-and-publications/publications/minerals-mining-publications/canadian-mineral-exploration/17762

EV battery mineral production is concentrated in a small number of countries. Many of these countries have authoritarian governments and questionable human rights and environmental governance practices. Supporting mineral exploration activities as a means to advance Canadian mining plays an important role in reducing North America's reliance on critical minerals imported from such countries. Canada's ability to identify mineral deposits also offers benefits to trading partners that seek to do the same.

5.1.3 - Potential Economic Impact

Table 5.1.2 summarizes the potential economic benefits of EV battery mineral exploration by 2030. Our analysis relies extensively on publicly available information reported by junior and senior mining companies in order to quantify output, GDP, and employment. The results of our analysis demonstrate that with sufficient government support, favourable market conditions, and strong commodity prices, EV battery mineral exploration could potentially contribute up to $800 million annually to Canadian GDP and support more than 6,000 jobs by 2030. Moreover, many of these benefits will be concentrated in northerly regions and in close proximity to First Nations communities.

The nominal contributions of mineral exploration are relatively small when compared to EV assembly, battery cell manufacturing, or mining. However, they represent an important step in unlocking opportunities elsewhere in the EV battery supply chain. The entire EV battery supply chain depends on minerals, and the process of mining and refining those minerals begins with exploration.

Table 5.1.2 - Potential Economic Impact of Mineral Exploration

	Scenarios 1 & 2	**Scenario 3**	**Scenario 4**
Output	$59,004,450	$277,411,430	$717,173,924
Direct GDP	$33,636,728	$158,144,223	$408,840,086
Indirect GDP	$14,667,799	$68,961,157	$178,280,842
Induced GDP	$17,390,138	$81,760,327	$211,369,715
Total GDP	$65,694,666	$308,865,707	$798,490,643
Direct Employment	270	1,270	3,284
Indirect Employment	120	563	1,454
Induced Employment	134	631	1,631
Total Employment	524	2,464	6,369

5.2 - Mining

5.2.1 - Overview

As the transition to EVs accelerates, the demand for the minerals used to manufacture rechargeable batteries that propel EVs is expected to increase considerably. The World Bank estimates that the global demand for EV battery minerals–such as graphite, lithium, and cobalt–will increase four to five times by 2050 while the demand for nickel will double.[50] Others, such as the International Energy Agency, estimate that demand for certain minerals, and specifically lithium, could increase sixfold by 2030.[51]

If these estimates are accurate, there will be a multitude of opportunities to grow Canada's mining industries over the next two decades. This is because Canada is among a handful of countries–and one of the few with a democratic government–that has the potential to supply battery manufacturers with most, if not all, of these minerals. This could translate into substantial economic benefits in terms of contributions to GDP, employment, and government revenues. The mining of EV battery minerals can also help integrate new regions and communities into domestic and international automotive and transportation-related production networks. This can help to expand geographically the prosperity associated with these industries, which have historically been concentrated in southern Ontario, Québec, and Manitoba.

While concerns exist regarding the carbon footprint of mining resulting from the increased demand for EV battery minerals, the World Bank estimates the GHG emissions associated with these activities will be only six per cent of those associated with fossil fuel-dependent technologies.[52] This does not mean that environmental concerns are being ignored, as investors, corporate ESG strategies, government policies, and consumer preferences are increasingly supportive of reducing the carbon footprint associated with mining. A strong environmental track record is, therefore, an important component of the transition to EVs. Canadian governments and industry stakeholders will have to be deliberate in expediting the process of developing mining resources and infrastructure in a manner that does not undermine environmental protections, ESG potential, and consent, partnerships and the rights of Indigenous peoples in Canada.

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[50] World Bank (2020) 'Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition', https://www.worldbank.org/en/news/press-release/2020/05/11/mineral-production-to-soar-as-demand-for-clean-energy-increases

[51] International Energy Agency (2021) 'Total lithium demand by sector and scenario, 2020-2040', https://www.iea.org/data-and-statistics/charts/total-lithium-demand-by-sector-and-scenario-2020-2040

[52] World Bank (2020) '"Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition', https://www.worldbank.org/en/news/press-release/2020/05/11/mineral-production-to-soar-as-demand-for-clean-energy-increases.

5.2.2 - Canada's Current Position

Mining is an important part of Canada's economy. Canada extracts more than 60 minerals from more than 200 mines and 6,500 quarries across the country, generating approximately $50 billion of output annually.[53] Nearly 75 per cent of that value was generated from gold, iron ore, coal, copper, and potash in 2019.[54] Mining activities directly contributed $31.8 billion to Canadian GDP and directly employed 69,510 people in 2020.[55] In proportional terms, mining accounted for 1.7 per cent of Canadian GDP and 0.4 per cent of total employment. The mining industry (BS212) accounted for 9 per cent of Canada's exports (by dollar value) in 2020, nearly two-thirds of which were destined for the EU and the United States.[56]

Mining provides high-paying jobs across Canada, often in northerly and remote regions. Average annual earnings for those employed in mining were $127,300 in 2020, more than twice the average for all Canadians.[57] Every mining job is estimated to generate between one and four additional jobs elsewhere in the economy, depending on the mineral (e.g. gravel quarries generate one additional job while diamond mines generate up to four).[58] Mining companies make significant contributions through royalties and corporate income taxes.

Canada holds an enviable position as it relates to the potential to mine battery minerals. The country ranks sixth globally in lithium reserves, seventh in nickel, and eighth in cobalt.[59] Canada is also developing graphite and manganese mining capabilities. That said, Canada mined virtually no lithium or manganese in 2021, the majority of nickel was used to supply steel and metalworking industries, and cobalt was produced primarily as a by-product of nickel extraction and refining.[60] A number of new mines and associated infrastructure must be developed if Canada is to capture any significant market share related to EV battery minerals by 2030. This may be a challenge given the number of factors mining companies and governments must consider during the planning and development of mining resources, especially those related to ESG.

Our research identified 21 EV battery mineral mines that are operational or could potentially be operational by 2030. Table 5.2.1 provides more information about these mines. Of these 21, nine are located in Québec, five in Ontario, three in British Columbia, two in New Brunswick, and one in each of Manitoba and the Northwest Territories. Note that Table 5.2.1 does not

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[53] Statistics Canada Table 36-10-0488-01 (formerly CANSIM 381-0031)
[54] Natural Resources Canada (2022) 'Minerals and Metals Facts', https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/20507
[55] Statistics Canada Table 36-10-0434-03 and Table 36-10-0480-01 (formerly CANSIM 383-0033)
[56] ISED Trade Data Online; https://www.ic.gc.ca/eic/site/tdo-dcd.nsf/eng/home
[57] Natural Resources Canada (2022) 'Minerals and the economy', https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/minerals-and-the-economy/20529
[58] Statistics Canada Table 36-10-0594-01
[59] U.S. Department of the Interior and U.S. Geological Survey (2022) 'Mineral Commodity Summaries 2022', https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf
[60] Natural Resources Canada (2022) 'Nickel facts', https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/nickel-facts/20519

include existing nickel (and related cobalt), iron, and copper mines. These mines may potentially supply EV battery minerals, but this would only require them to reallocate the final destination of their products and not correspond to significant changes in economic output.[61]

Table 5.2.1 - Select Canadian EV Battery Mineral Mining Projects

Mineral	Company	Project Name	Province	Stage
Cobalt	Fortune Minerals	NICO	NT	Advanced
Lithium	Allkem	James Bay	QC	Advanced
	Critical Elements	Rose	QC	Advanced
	Nemaska Lithium	Whabouchi	QC	Advanced
	Sayona Mining	Abitibi Hub	QC	Advanced
	Sayona Mining	Northern Hub	QC	Early
	Frontier Lithium	PAK/SPARK	ON	Early
	Rock Tech	Georgia Lake	ON	Early
Graphite	Eagle Graphite	Black Crystal	BC	Advanced
	Northern Graphite	Lac des Isles	QC	Advanced
	Northern Graphite	Bissett Creek	ON	Advanced
	Nouveau Monde	Matawinie	QC	Advanced
Nickel	Nion Nickel	Dumont	QC	Advanced
	Canada Nickel	Crawford	ON	Early
	Flying Nickel	Minago	MB	Early
	FPX Nickel	Baptiste	QC	Early
	Giga Metals	Turnagain	BC	Early
	Wyloo Metals	Eagle's Nest (Ring of Fire)	ON	Early
Manganese	Canadian Manganese	Woodstock	NB	Early
	Manganese X	Battery Park	NB	Early
Phosphate	Arianne Phosphate	Lac a Paul	QC	Early

[61] Our estimates do not include Vale Canada's recent agreements to supply NorthVolt and Tesla with Class 1 nickel due to the lack of information provided by the company about timelines or volumes.

The mines outlined in Table 5.2.1 can help Canada become an important EV battery mineral supplier. Bringing them online requires substantial capital expenditures as well as significant resources devoted to regulatory compliance. Moreover, most of these projects are located in sparsely populated regions. Infrastructure development will be necessary for these mines to become operational. Their development timelines may also be sensitive to fluctuations in commodity prices.

Recently-announced federal and provincial government programs related to mining are encouraging. The $3.8 billion plan to support the mining industry outlined in the recent federal budget is particularly significant. In addition to the federal government, Ontario, Québec, Alberta, and Newfoundland and Labrador have all released critical minerals strategies that emphasize EV battery materials. As part of these strategies, a series of policy instruments and financial incentives have been implemented to support mining. These include a mix of preferential tax rates, tax credits and rebates, targeted investment funds, workforce development and immigration programs, and R&D centres to support mining innovation.

Canadian governments have been motivated by the potential to secure domestic and continental supply chains. EV battery mineral production is concentrated in a small number of countries (Figure 5.2.1) and Canada ranks among the top 10 in reserves and mine production of several such minerals (Table 5.2.2). Disruptions arising from the COVID-19 pandemic and more recently, the invasion of Ukraine by Russia, underscore the fragility of global supply chains. They also demonstrate that building a reliable EV battery mineral supply chain is strategically important. In this context, several international inter-governmental initiatives are underway, including the Canada-U.S. Joint Action Plan on Critical Minerals and the Canada-EU Strategic Partnership on Raw Materials.[62]

Investors, governments, consumers, and other stakeholders have a heightened level of attention to the environmental and human rights records and policies of countries where these materials are mined. A country's political stability and position within global political alliances also receive an increasing amount of attention. Canada's robust regulatory frameworks governing mining and minerals align well with these priorities and can be leveraged to attract investment in EV battery mineral projects.

[62] Natural Resources Canada (2020) 'Canada and U.S. Finalize Joint Action Plan on Critical Minerals Collaboration', https://www.canada.ca/en/natural-resources-canada/news/2020/01/canada-and-us-finalize-joint-action-plan-on-critical-minerals-collaboration.html;
Natural Resources Canada (2021) 'Joint Statement by Canada's Minister of Natural Resources and the European Commissioner for Internal Market', https://www.canada.ca/en/natural-resources-canada/news/2021/07/joint-statement-by-canadas-minister-of-natural-resources-and-the-european-commissioner-for-internal-market.html.

Figure 5.2.1 - Global Nickel, Cobalt, Lithium, and Graphite Mine Production, 2021 [63]

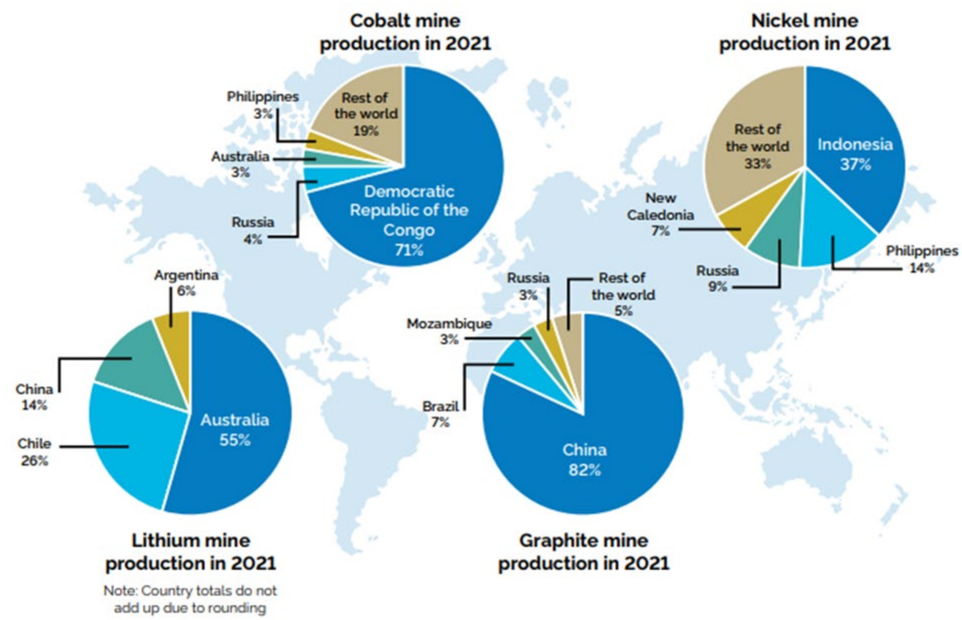

Table 5.2.2 - Canada's Global Ranking, Select EV Minerals, 2020 [64]

Mineral	Reserves	Mine Production
Lithium	6	n/a
Nickel	7	6
Cobalt	8	6
Graphite	n/a	10
Manganese	n/a	n/a
Phosphate	n/a	n/a

[63] As published in Government of Ontario (2022) 'Ontario's Critical Minerals Strategy: Unlocking potential to drive economic recovery and prosperity', https://www.ontario.ca/files/2022-03/ndmnrf-ontario-critical-minerals-strategy-2022-2027-en-2022-03-22.pdf

[64] Natural Resources Canada (2022) 'Minerals and Metals Facts', https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/20507

5.2.3 - Potential Economic Impact

To quantify the potential economic impact of mining and mineral exploration we estimate the amount of production in 2030 of each of the minerals considered in this report (Table 5.2.3). These estimates are based on publicly available information associated with the mines listed in Table 5.2.2 and our own assessment of the likelihood that those mines will be online in 2030 (see Section 3.2). Note that Table 5.2.3 does not include existing nickel (and related cobalt), iron, and copper mines. These mines may potentially supply EV battery minerals, but this would only require them to reallocate the final destination of their products and not correspond to significant changes in economic output.[65] Figures 5.2.2 through 5.2.7 illustrate these production assumptions relative to estimated demand in Canada and the United States.

Table 5.2.3 - Estimated Annual Canadian EV Mineral Production (Tonnes)

Mineral	Scenarios 1 & 2	Scenario 3	Scenario 4
Cobalt	-	1,800	3,977
Lithium[66]	321,000	940,327	1,410,327
Graphite	122,500	142,500	142,500
Nickel	-	50,000	187,500
Manganese	-	-	128,168
Phosphate	-	142,384	214,275

Figures 5.2.2 through 5.2.7 show that Canada has the potential to be an important supplier of lithium and graphite by 2030.[67] Nickel mining also presents a potentially substantial opportunity for Canada given the relatively high number of early-stage mines. Manganese and phosphate projects are limited in number, but could potentially supply a large proportion of the North American market. Opportunities in stand-alone cobalt mining are limited because of the propensity to extract this mineral as a by-product of nickel mining and refining. While outside the scope of this report, our more ambitious scenarios highlight the significant opportunity to supply lithium and nickel to global markets beyond North America, as indicated by green bars showing Canadian production volumes exceeding the orange bars of Canada-US demand in the figures below.

[65] Our estimates do not include Vale Canada's recent agreements to supply NorthVolt and Tesla with Class 1 nickel due to the lack of information provided by the company about timelines or volumes.

[66] Lithium spodumene concentrate.

[67] Other sources of lithium, such as extraction from brine, have also been identified. Several of these sources are located in Alberta. However, we assess their ability to be major suppliers to the EV battery supply chain by 2030 as low. They may become important suppliers by 2040.

To estimate the total output value for each mineral we multiply the estimated quantities in Table 5.2.3 with the projected commodity prices in Appendix III. We use these output values to quantify contributions to GDP and employment. The potential economic impact of EV battery mineral mining are detailed in Table 5.2.4. They show that under the more ambitious scenarios, this node could contribute between $1.8 and $4.5 billion annually to GDP and support between 8,879 and 21,174 jobs by 2030.

Figure 5.2.2 - Estimated Canadian Lithium Production and Canada & US Demand

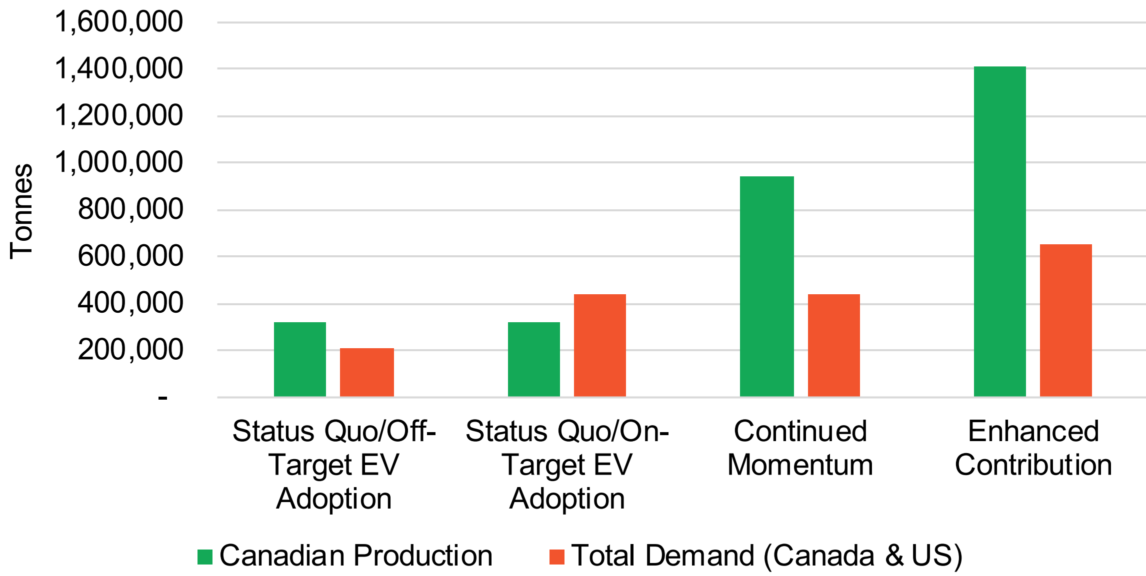

Figure 5.2.3 - Estimated Canadian Nickel Production and Canada & US Demand

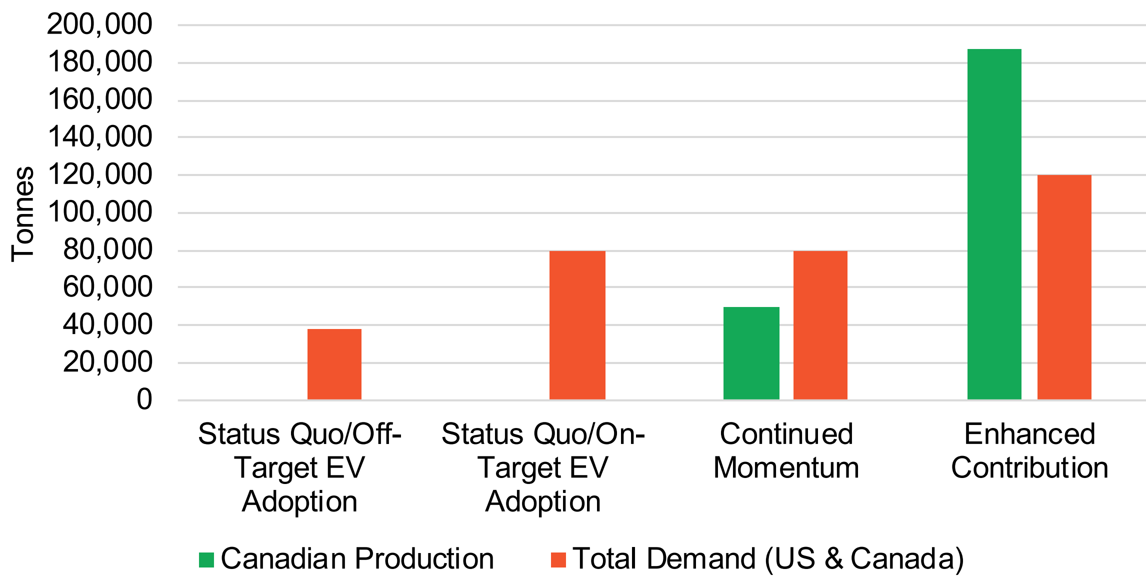

Figure 5.2.4 - Estimated Canadian Cobalt Production and Canada & US Demand

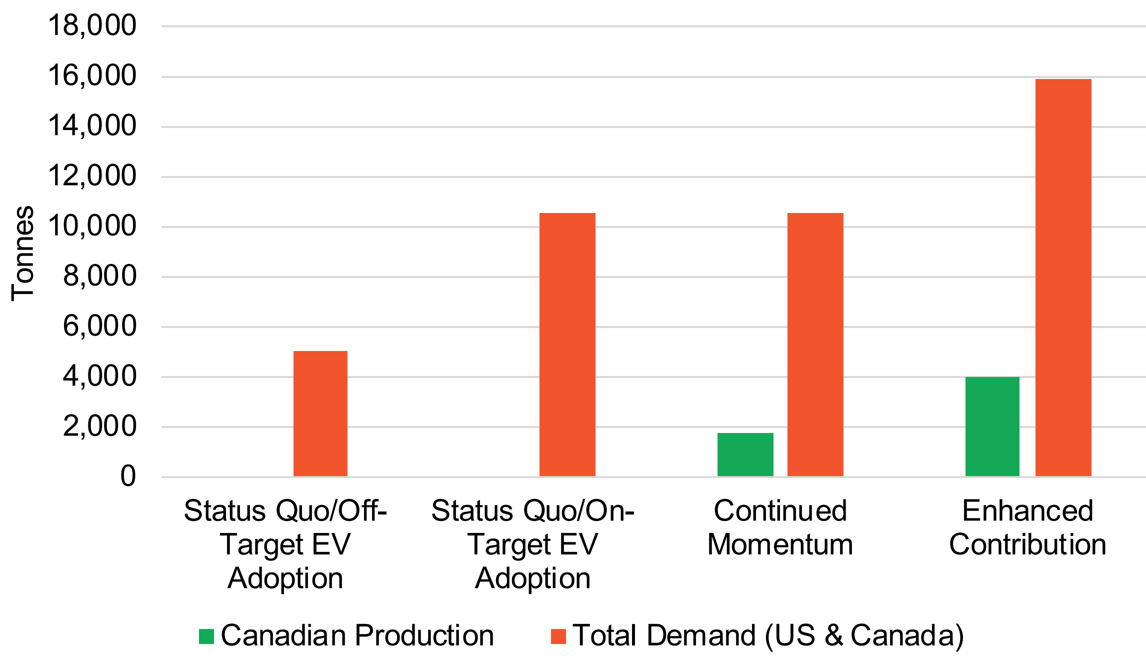

Figure 5.2.5 - Estimated Canadian Graphite Production and Canada & US Demand

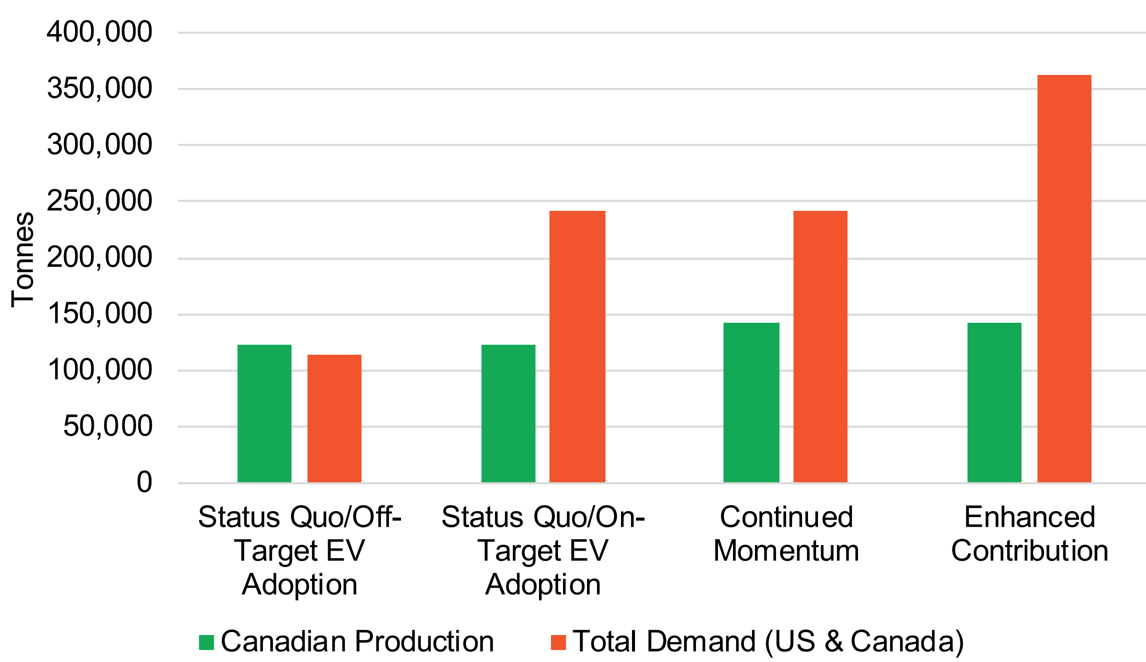

Figure 5.2.6 - Estimated Canadian Manganese Production and Canada & US Demand

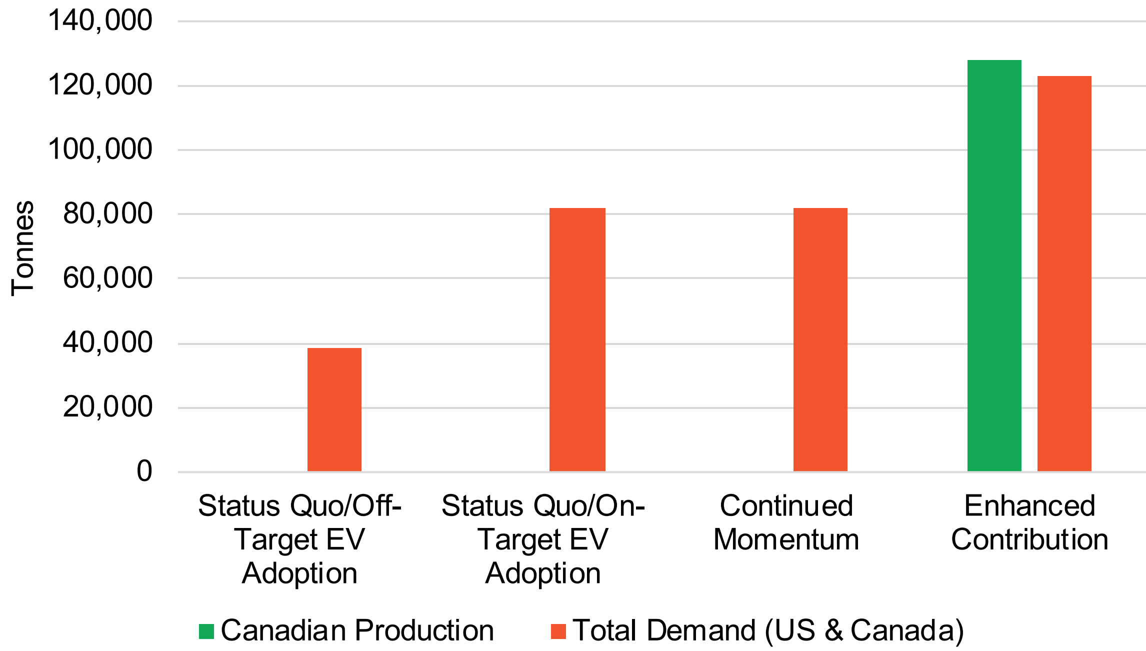

Figure 5.2.7 - Estimated Canadian Phosphate Production and Canada & US Demand

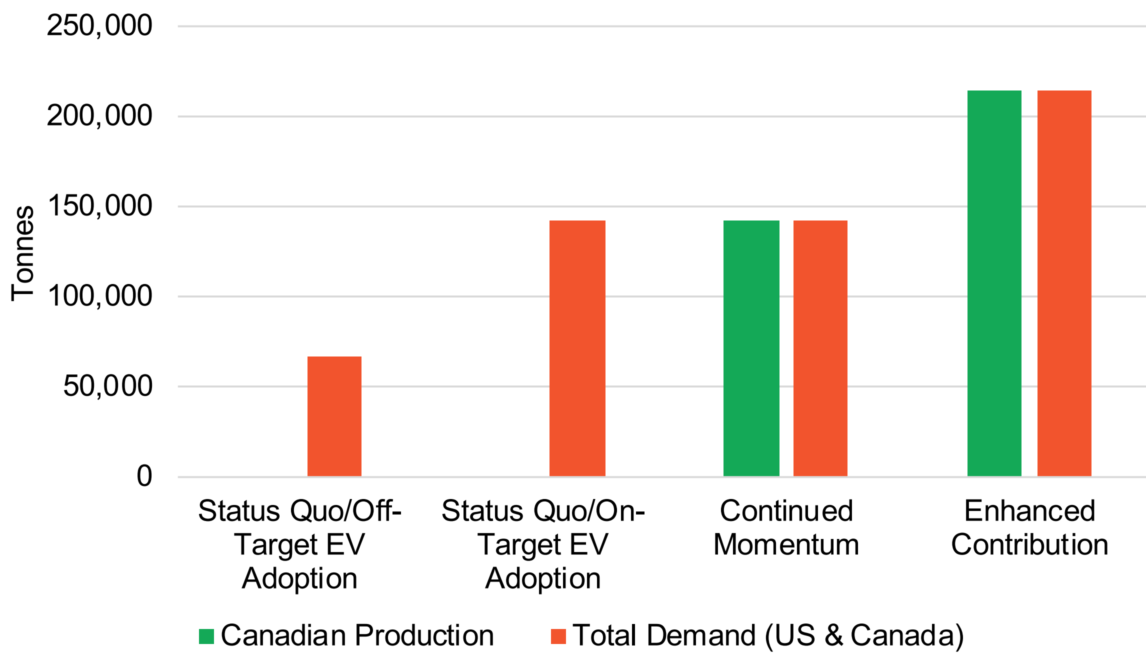

Table 5.2.4 - Potential Economic Impact of Mining

	Scenarios 1 & 2	Scenario 3	Scenario 4
Output	$393,363,000	$1,849,409,531	$4,781,159,492
Direct GDP	$249,246,644	$1,174,760,840	$3,047,430,799
Indirect GDP	$93,773,361	$338,274,013	$769,875,386
Induced GDP	$71,667,647	$298,001,707	$728,597,011
Total GDP	$414,687,652	$1,811,036,560	$4,545,903,196
Direct Employment	982	3,386	7,408
Indirect Employment	703	3,194	8,144
Induced Employment	553	2,300	5,622
Total Employment	2,238	8,879	21,174

5.3 - Battery Material Production

5.3.1 - Overview

Battery material production refers to the refining and further processing of minerals to transform them into cathode, anode, and electrolyte materials. These materials comprise a sizable portion of a battery cell's value. Their production, despite being an intermediate step in the EV battery supply chain, creates a significant amount of value-added activity.

Several processes are required to manufacture battery materials. For example, mineral ores such as lithium, cobalt, and manganese are first refined into precursor materials. These precursors are subsequently combined to produce CAM. Graphite is also refined into higher-purity forms to produce anode materials.

The drive to reduce the cost of batteries to facilitate widespread consumer adoption of EVs will affect the amount and type of battery materials required in the future. One approach to reducing the cost of batteries involves replacing more costly and scarce minerals with less costly alternatives without compromising battery performance. The Trillium Network model assumes a certain market share for each type of EV batteries as detailed in the Methodology section to estimate battery material demand.

Like mining, battery materials production is concentrated in a small number of countries. In 2019, approximately 90 per cent of global CAM and anode material and 81 per cent of electrolyte production took place in China, Japan, and South Korea. Chile and Argentina were the leading producers and exporters of lithium carbonate and China was the leading producer of lithium hydroxide.[68] China was also the world's leading producer of cobalt sulphate.[69] China, Japan, and South Korea account for virtually all of the world's nickel sulphate production.[70]

Battery material production represents a gap in the North American EV supply chain. This gap is highlighted in the U.S. Department of Energy's *National Blueprint for Lithium Batteries*, which prioritizes the development of a battery materials manufacturing industry in order to meet domestic demand.[71]

Battery material production is an energy-intensive process. CAM, anode material, and electrolyte production account for nearly 60 per cent of the total energy requirements necessary to produce an EV battery pack.[72] Sourcing battery materials from facilities that use electricity generated by low-emissions sources will be an important consideration for automakers seeking to reduce their carbon footprint. Jurisdictions that generate electricity from low-emissions sources may therefore hold a competitive advantage.

5.3.2 - Canada's Current Position

Canada's EV battery material manufacturing capacity was until recently limited to a Johnson Matthey facility in Candiac, Québec, that produced lithium iron phosphate cathode materials. That facility was recently sold by Johnson Matthey to Nano One Materials.[73] However, two recent investments (General Motors-POSCO and BASF) will increase Canada's CAM production capacity considerably. These investments, which are both located in Bécancour, Québec, will potentially increase Canada's projected CAM production capacity from negligible levels to between 30 and 60 per cent of North American demand for CAM by 2030.

A number of smaller facilities that will manufacture precursor materials are anticipated to come online by 2030. Our research identified 16 companies and 17 projects that have the potential to increase Canada's production capacity substantially (Table 5.3.1). Once operational, these projects have the potential to capture a substantial proportion of the North American market for

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68 Zhang, Y., Z. Dong, S. Liu and P. Jiang (2021) 'Forecast of International Trade of Lithium Carbonate Products in Importing Countries and Small-Scale Exporting Countries' *Sustainability* 13(3): 1251.

69 Electra Battery Materials (2022) 'Investor Presentation', https://electrabmc.com/wp-content/uploads/2022/03/03_15_22-Electra-BMC-March-2022-1.pdf.

70 Roskill (2021) 'Study on future demand and supply security of nickel for electric vehicle batteries', https://publications.jrc.ec.europa.eu/repository/bitstream/JRC123439/roskill-jrc_classi_ni_market_study_identifiers_final.pdf.

71 U.S. Department of Energy (2021) 'National Blueprint for Lithium Batteries 2021-2030', https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf.

72 Emilson, E. and L. Dahllöf (2019) 'Lithium-Ion Vehicle Battery Production - Status 2019 on Energy Use, CO2 Emissions, Use of Metals, Products Environmental Footprint, and Recycling', IVL Swedish Environmental Research Institute, https://www.ivl.se/download/18.14d7b12e16e3c5c36271070/1574923989017/C444.pdf.

73 Johnson Matthey (2022) 'Nano One to Acquire Johnson Matthey Battery Materials Canada, 25 May 2022, https://matthey.com/nano-one-to-acquire-johnson-matthey-battery-materials-canada

EV battery materials. They could also potentially export materials to battery manufacturers in the EU.

Table 5.3.1 - Select Canadian Battery Material Production Investments

Material	Company	Location
Anode Material	Nouveau Monde Graphite (Phase 1)	Bécancour, QC
	Nouveau Monde Graphite (Phase 2)	Bécancour, QC
CAM	BASF	Bécancour, QC
	General Motors-POSCO	Bécancour, QC
Cobalt Sulphate	Electra Battery Materials	Cobalt, ON
	Fortune Minerals	Lamont County, AB
Lithium Carbonate	Avalon-Essar Group	Thunder Bay, ON
	Nemaska Lithium	Bécancour, QC
	Sayona Mining	TBD, QC
Lithium Hydroxide	E3 Metals	TBD, AB
	Critical Elements	TBD
	Frontier Lithium	TBD
	Nemaska Lithium	Bécancour, QC
Manganese Sulphate	Manganese X Energy	Woodstock, NB
Nickel Sulphate	Electra Battery Materials	Cobalt, ON
	FPX Nickel	TBD
Phosphoric Acid	Arianne Phosphate	Belledune, NB

5.3.3 - Potential Economic Impact

To quantify the potential economic impact of battery materials manufacturing, we estimate the amount of production in Canada in 2030 of each material considered in our study. These estimates are guided by publicly available information related to the projects listed in Table 5.3.1 and our assessment of the likelihood that these projects will be operational in 2030. Scenarios 3 and 4 also assume Canada develops additional CAM and electrolyte production capacity, and Scenario 4 assumes additional capacity to produce anode materials to meet growing North American demand. These assumptions are summarized in Table 5.3.2, while Figures 5.3.1

through 5.3.8 illustrate production assumptions relative to the estimated demand for battery materials in Canada and the United States.

Figures 5.3.1 through 5.3.8 show that Canada currently lacks short-term battery material processing capability, with the exception of cobalt sulphate and CAM. When we consider these data alongside our mining estimates, it becomes apparent that supporting the development of lithium, nickel, and anode material (e.g. graphite) production capacity offers a potentially meaningful opportunity for Canada to capture economic benefits associated with domestically-mined battery minerals. Moreover, while opportunities to process manganese and phosphate and to manufacture electrolytes may be economically valuable, there are currently too few projects in planning through which Canada could build significant production capacity by 2030.

To estimate the value of battery material production output we multiply the quantities found in Table 5.3.2 by the commodity price estimates in Appendix III. We then use these output estimates to quantify contributions to GDP and employment. Table 5.3.3 summarizes the economic impact of battery material production.

Table 5.3.2 - Estimated Annual Battery Material Production (Tonnes except where noted)

Material	**Scenarios 1 & 2**	**Scenario 3**	**Scenario 4**
Anode Material	2,000	44,000	63,586
CAM	130,000	260,000	350,000
Cobalt Sulphate	32,500	37,237	37,237
Lithium Carbonate/ Hydroxide (LCE)	0	47,890	163,075
Manganese Sulphate	0	0	50,000
Nickel Sulphate	0	268,697	483,330
Phosphoric Acid	0	0	303,936
Electrolyte (litres)	0	7,691,120	23,147,577

Figure 5.3.1 - Estimated Canadian Refined Lithium Production and Canada & US Demand [74]

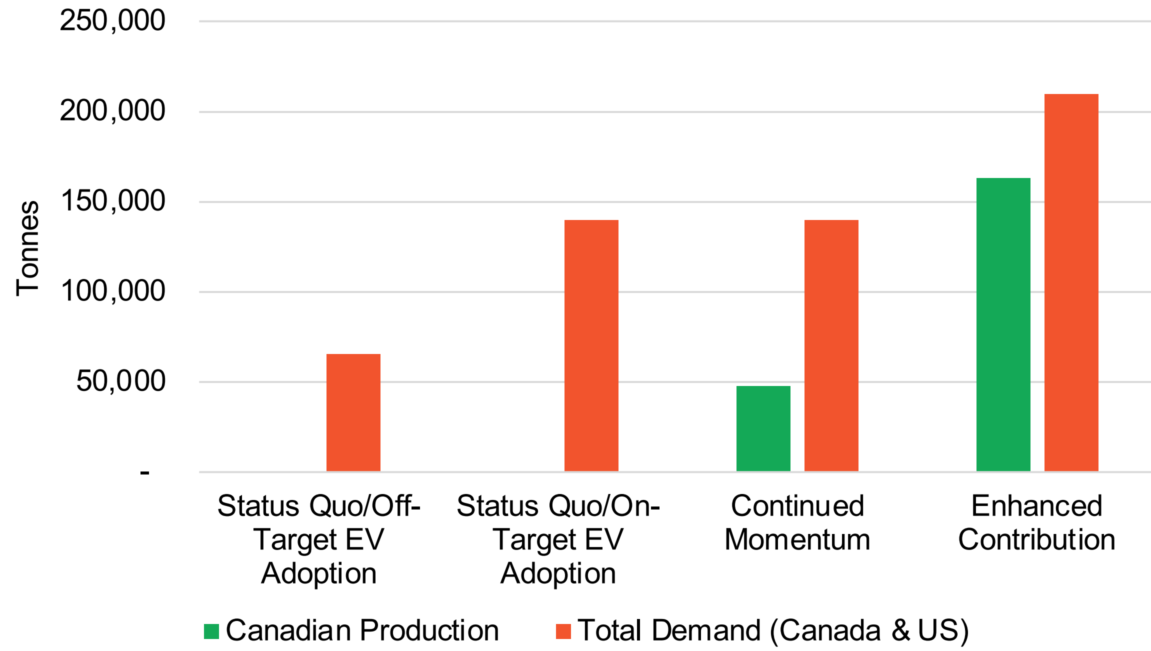
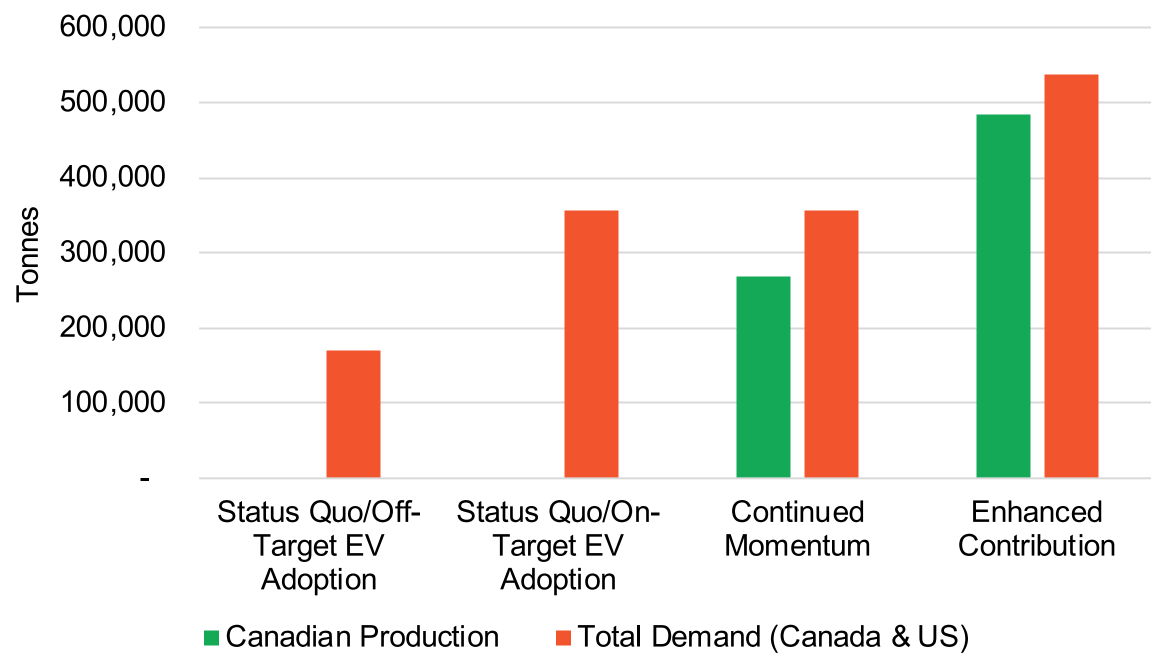


Figure 5.3.2 - Estimated Canadian Nickel Sulphate Production and Canada & US Demand



[74] In lithium carbonate equivalent (LCE) units.

Figure 5.3.3 - Estimated Canadian Cobalt Sulphate Production and Canada & US Demand

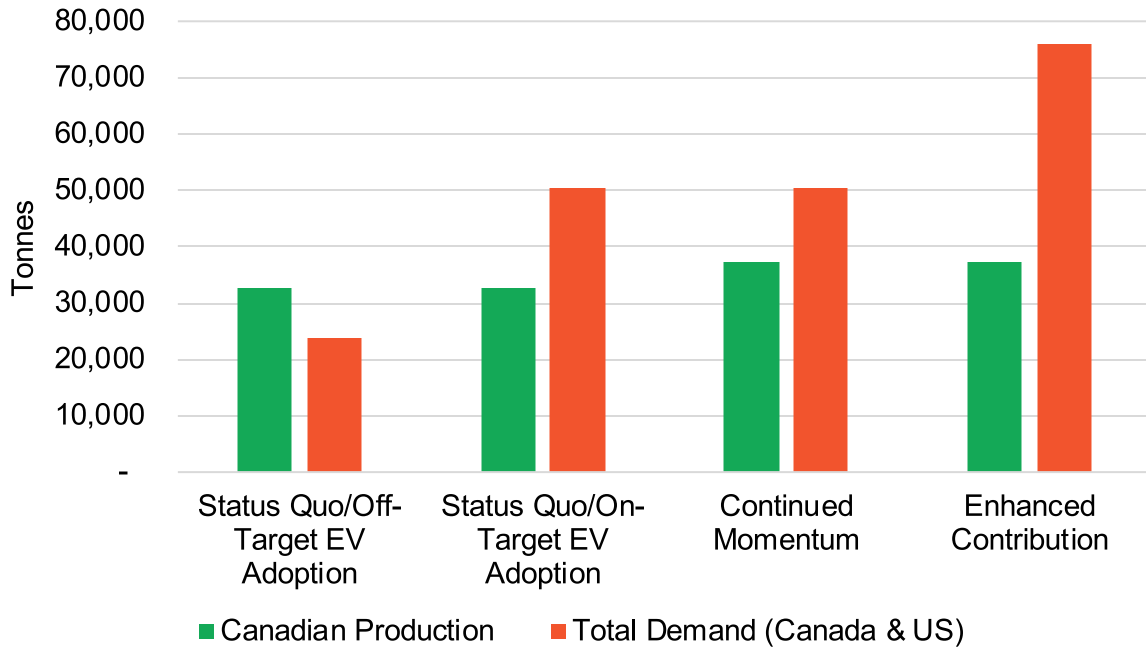


Figure 5.3.4 - Estimated Canadian Manganese Sulphate Production and Canada & US Demand

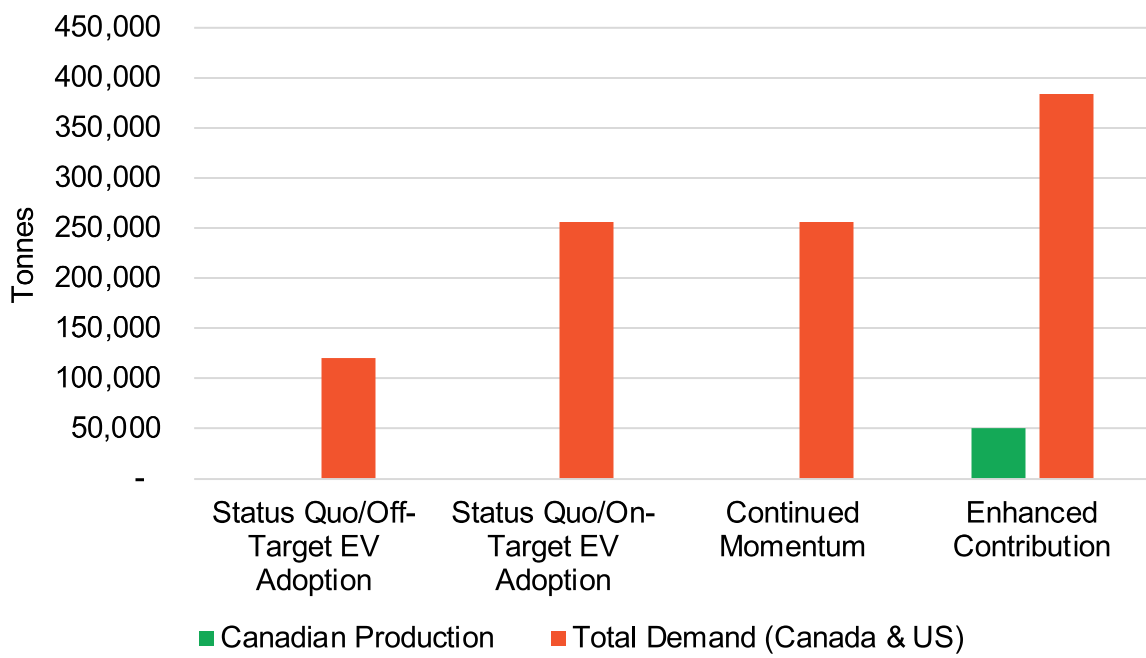


Figure 5.3.5 - Estimated Canadian Phosphoric Acid Production and Canada & US Demand

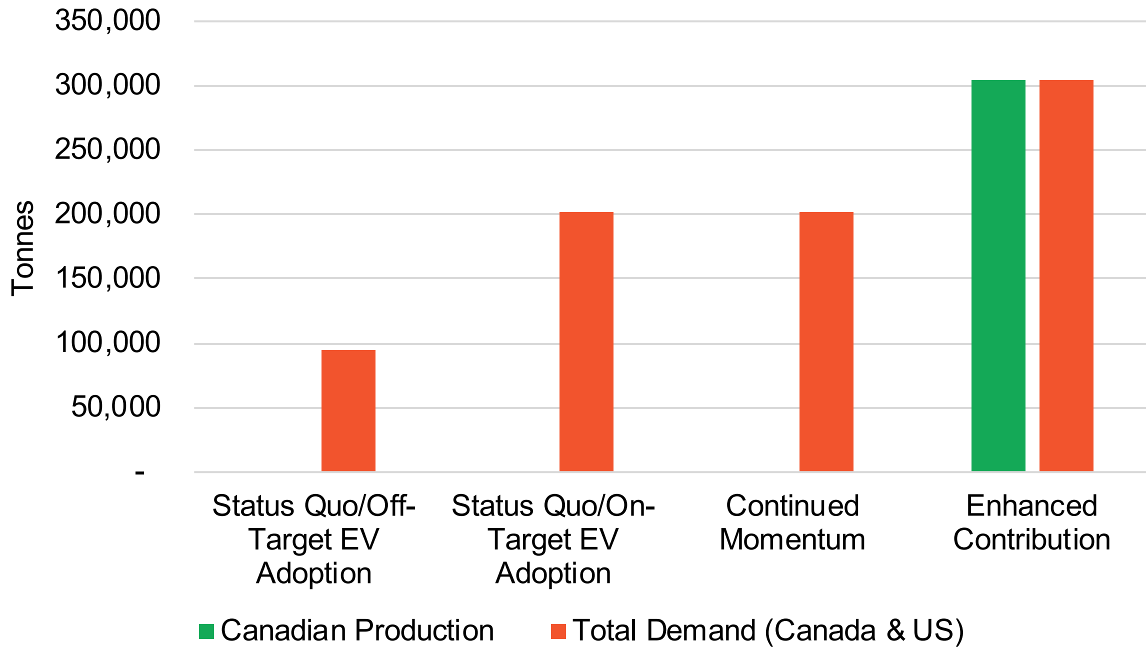


Figure 5.3.6 - Estimated Canadian CAM Production and Canada & US Demand

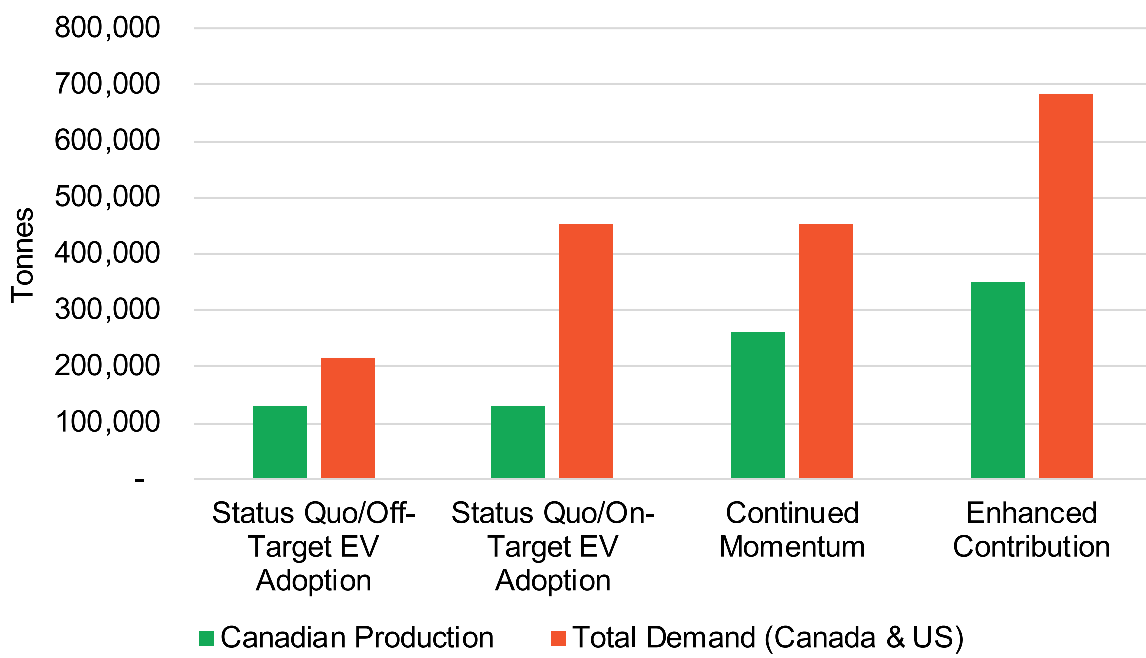


Figure 5.3.7 - Estimated Canadian Anode Material Production and Canada & US Demand

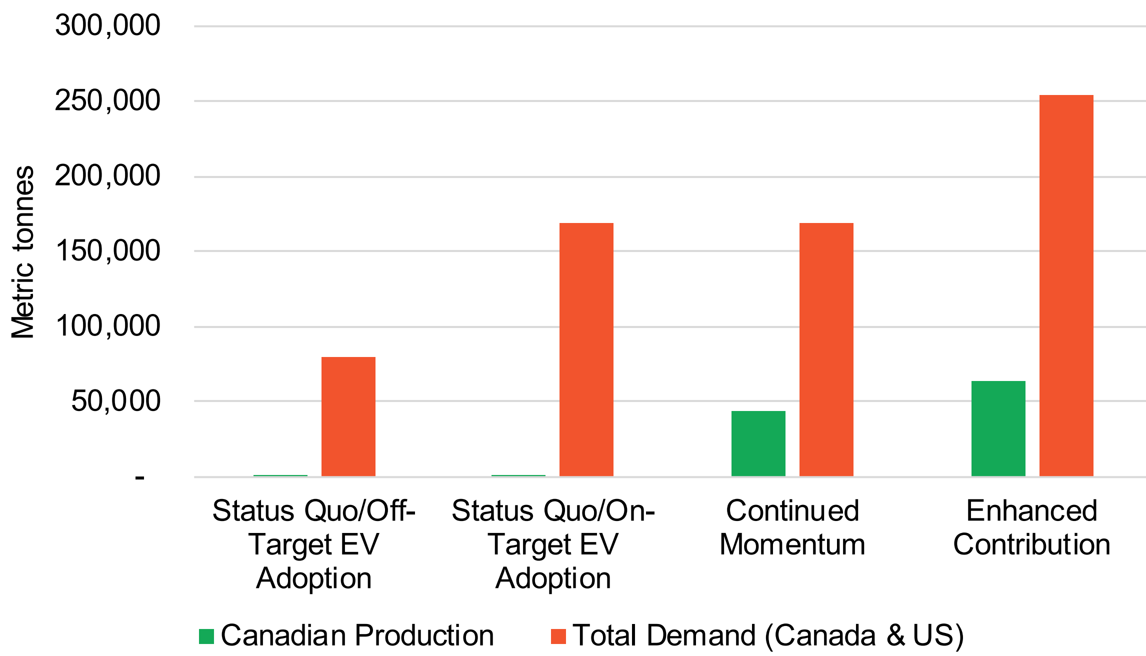


Figure 5.3.8 - Estimated Canadian Electrolyte Production and Canada & US Demand

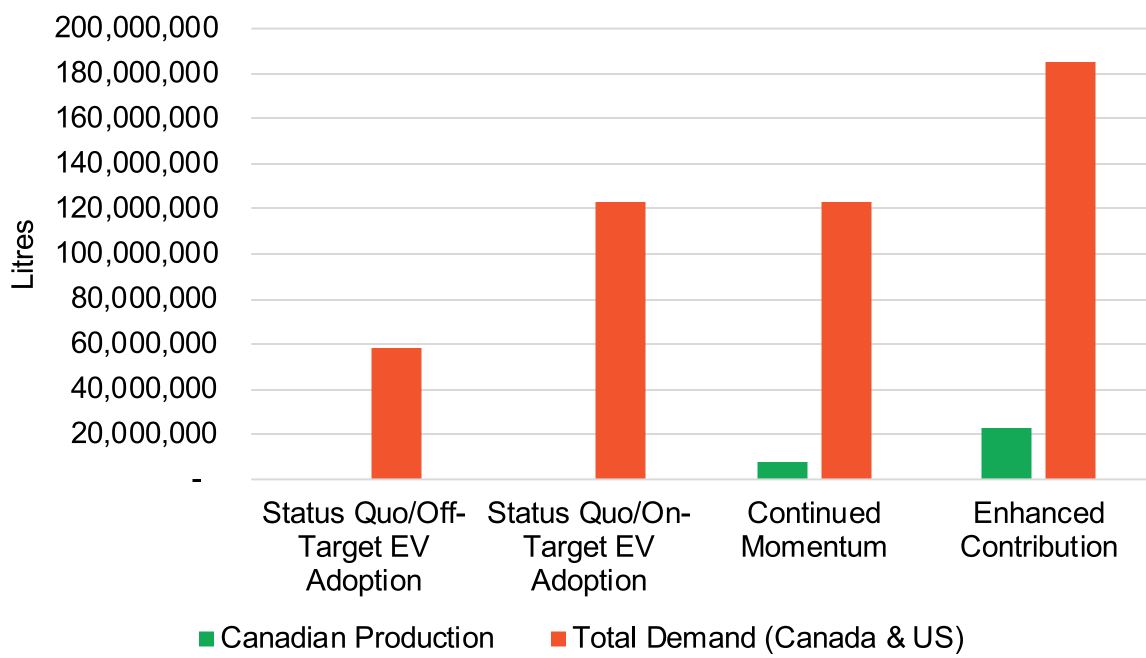


Table 5.3.3 - Potential Economic Impact of Battery Material Production

	Scenarios 1 & 2	Scenario 3	Scenario 4
Output	**$3,962,400,000**	**$10,452,922,480**	**$16,522,800,642**
Direct GDP	$1,279,111,768	$3,399,586,098	$5,370,509,388
Indirect GDP	$974,849,532	$2,585,350,767	$4,084,913,309
Induced GDP	$428,306,584	$1,157,437,199	$1,826,084,496
Total GDP	$2,682,267,884	$7,142,374,063	$11,281,507,192
Direct Employment	2,316	7,180	11,216
Indirect Employment	9,343	24,758	39,121
Induced Employment	3,305	8,932	14,091
Total Employment	14,965	40,870	64,428

Table 5.3.3 shows that in Scenarios 1 and 2, battery material production activities will directly contribute $1.3 billion annually to Canadian GDP and directly employ 2,316 persons. These contributions increase to $2.7 billion in GDP and 14,965 jobs when indirect and induced activities are considered. Much of this economic activity is related to the General Motors-POSCO and BASF investments.

If Canada attracts further investment in battery materials production, these activities could directly contribute between $3.4 and $5.4 billion annually to GDP and directly employ between 7,180 and 11,216 persons. These contributions increase to between $7.1 and $11.3 billion and 40,870 and 64,428 jobs when indirect and induced activities are considered.

These estimates underscore the size and significance of the potential economic benefits associated with battery material production vis-a-vis mining. While developing battery material production capacity is not contingent upon nearby mining activities, Canada can potentially strengthen its position by capitalizing on its mining capabilities and geographic proximity to North America's largest battery cell manufacturing facilities to attract further investment. While the gap in battery material manufacturing represents a significant opportunity, it is important to recognize that the United States has similarly ambitious plans that will lead to competition for investments (and for Canadian-mined minerals).

Building battery material manufacturing capacity offers an opportunity to capture considerably more value from domestic mining than simply mining the materials in Canada and exporting them. Moreover–and if we take Canada's aluminum industry as an example–it is possible to build a battery materials manufacturing industry that relies partially or temporarily on minerals imported from other democratically-governed trading partners with reputations for responsible environmental and social governance.

5.4 - Battery Component Manufacturing

5.4.1 - Overview

Battery component manufacturing refers to the production of a number of parts that are adjacent to EV batteries. The majority of these components are not normally found in ICEVs. They include separators, positive and negative collectors, cell hardware (e.g. containers, sleeves), module hardware (e.g. housing, thermal conductors, terminals), pack hardware (e.g. trays, compression structures, housings), and EV-specific thermal management systems (TMS) and battery management systems (BMS). Some components are made of metal or polymers (e.g. trays, housings), while others are more closely associated with electrical equipment and electronics. These components are identified in the BatPaC model.[75]

Automotive parts manufacturing is subject to a certain geographic logic. Certain products, such as front-end modules, cockpit assemblies, and seats, are almost always produced in close proximity to vehicle assembly plants. This is due to automakers' preference for just-in-time (and just-in-sequence) production systems and the high cost of shipping bulky products. These modules are themselves made up of dozens (or even hundreds) of smaller parts and components that are manufactured across North America or, in some cases, overseas. Smaller parts and components may cross several international borders before they reach their final destination.

The complex and integrated nature of automotive production networks, when combined with a certain amount of confidentiality that exists between automakers and suppliers, makes it difficult to estimate the exact quantity or value of any given component produced in any national or sub-national jurisdiction. The Trillium Network model therefore relies on broader North American market share assumptions to guide our analysis.

The United States-Mexico-Canada Agreement (USMCA) will affect the geographic organization of the EV battery components industry in North America. Under the USMCA, vehicles are only afforded tariff-free treatment if they meet regional value content requirements and content origin rules. The USMCA is therefore expected to facilitate a substantial shift in the production of EV battery components from Asia to North America. Asian-owned companies with EV battery component manufacturing expertise but no North American footprint may seek to invest in North America to avoid tariffs. It is, however, still unclear where in North America these components will be manufactured, although there is a general expectation that most investment will be located near existing production networks.

[75] Argonne National Laboratory (2022) 'BatPaC: Battery Manufacturing Cost Estimation', https://www.anl.gov/partnerships/batpac-battery-manufacturing-cost-estimation

5.4.2 - Canada's Current Position

Unlike mining and battery materials, a large proportion of EV battery component manufacturing is within the purview of traditional automotive parts manufacturers. The automotive parts manufacturing industry in Canada directly employs upwards of 70,000 people[76] (a number that is actually between 30% and 40% higher according to some),[77] contributes more than $9 billion annually to GDP, and is responsible for approximately 7.5 per cent of North American output.[78] However, EV battery components account for a very small proportion of overall Canadian automotive parts manufacturing. Out of more than 1,000 establishments in Canada that manufacture automotive parts, only 15 could be identified through this research that manufactured EV battery components for use by original equipment manufacturers (i.e. automakers). These include establishments operated by both established globally competitive manufacturers (e.g. Magna, Dana, Mitsui) and new entrants.

Very little publicly available information about the future production plans of automotive parts suppliers operating in Canada exists. Some companies aspire to add EV battery components to their product portfolios as demand increases. Very few will do so, however, without orders from their automaker and upper-tier supplier customers.

While EV battery component manufacturing in Canada is currently limited, two recent announcements demonstrate that Canada can successfully compete for such investments. The first is Magna's new contract to supply battery enclosures for the Ford F-150 Lightning[79], which is assembled in Dearborn, Michigan. The second is the Korea-based Solus Advanced Materials' plant in Granby, Québec. This plant will supply Tesla and Panasonic with copper foils (also known as negative current collectors) used in EV battery anodes. These investments provide optimism that other Canadian suppliers will invest in new or existing production facilities as demand for EV battery components increases. Canadian-owned companies such as Magna and Linamar currently manufacture a considerable amount of EV battery components in Michigan. There are also United States-, Germany-, France-, and Japan-based suppliers that manufacture EV battery components *and* have a footprint in Canada (e.g. Tenneco, ZF, Faurecia, Aisin, Denso).

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[76] Statistics Canada Table 36-10-0480-01 (formerly CANSIM 383-0033)

[77] Sweeney, B. and G. Mordue (2017) 'The Restructuring of Canada's Automotive Industry, 2005-2014', *Canadian Public Policy*, 43 (S1): S1-S15

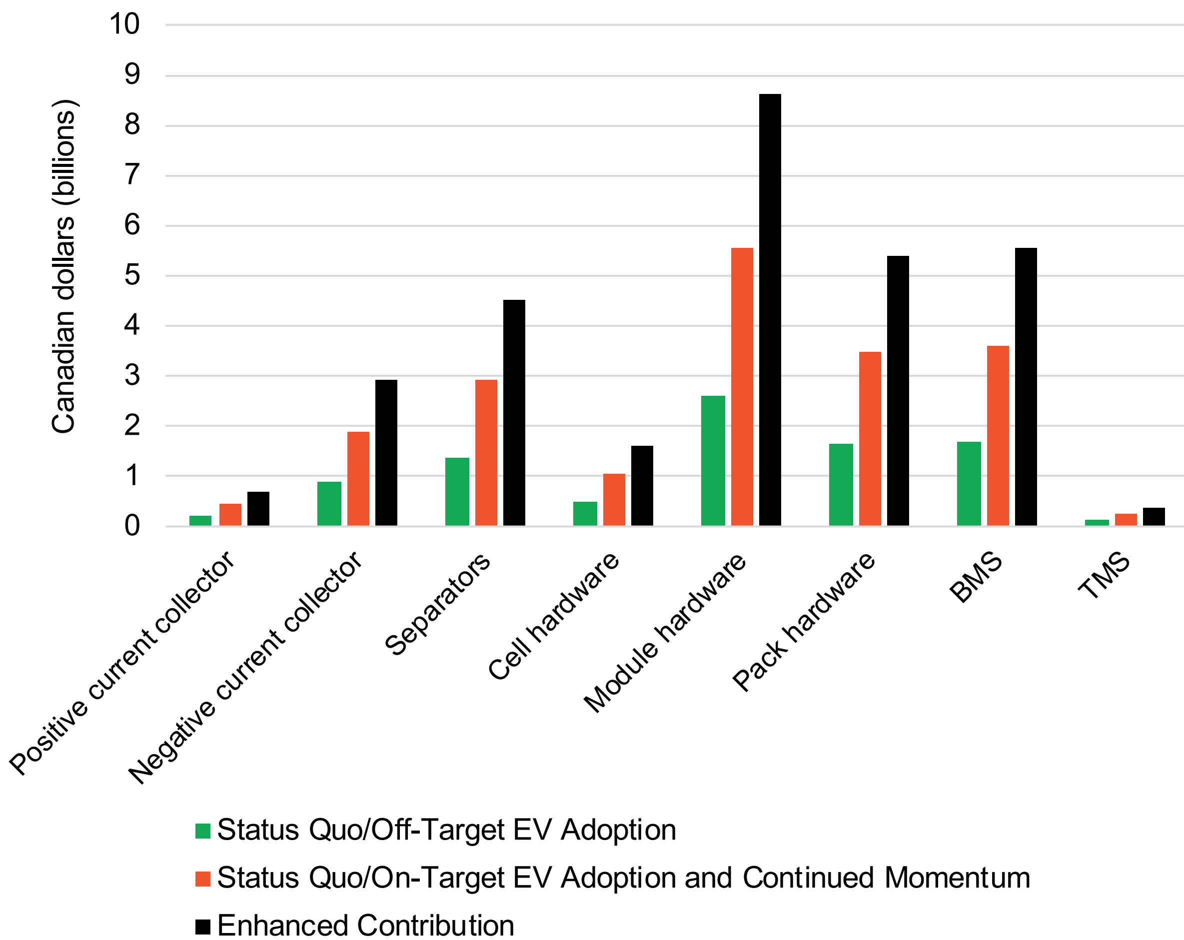
[78] Authors' Calculations, U.S. Bureau of Economic Analysis Table U.Gross Output by Industry - Detail Level, Statistics Canada Table 36-10-0488-01 (formerly CANSIM 381-0031), and the U.S. International Trade Administration Table Mexican Autoparts Market for OEM and Aftermarket, https://www.trade.gov/country-commercial-guides/mexico-automotive-industry)

[79] Magna International (2021) 'Magna Helps Ford Electrify the Future With Battery Enclosures for F-150 Lightning', https://www.magna.com/company/newsroom/releases/release/2021/11/09/news-release---magna-helps-ford-electrify-the-future-with-battery-enclosures-for-f-150-lightning

5.4.3 - Potential Economic Impact

To estimate the economic benefits of EV battery component manufacturing, we first estimate the market size of these components across Canada and the United States. These are informed by battery component prices obtained from the BatPaC model, our EV production and average battery capacity assumptions. Figure 5.4.1 illustrates these estimates.

Figure 5.4.1 - Estimated Demand for EV Battery Components in Canada and the US



These demand projections are based on broader North American market share assumptions as detailed in Appendix IV and other assumptions related to battery component prices and battery component projects as detailed in Appendix III are used to estimate output related to the manufacture of EV battery components in Canada. Figure 5.4.2 provides a summary of output for select components as well as the estimated North American market share for each scenario. The output values in Figure 5.4.1 are then used to calculate the economic impact of Canadian EV battery component manufacturing. Table 5.4.1 summarizes the economic impact of Canadian EV battery component manufacturing.

Figure 5.4.2 - Estimated Annual Canadian Output, Select EV Battery Components

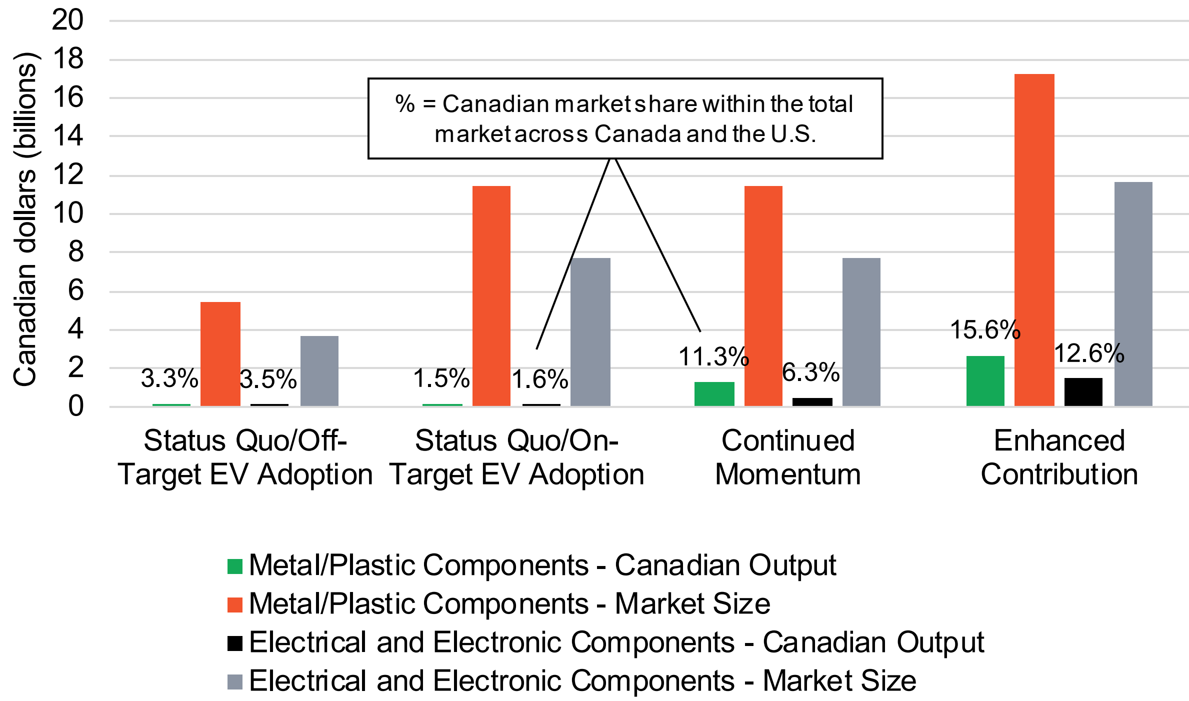


Table 5.4.1 - Potential Economic Impact of EV Battery Component Manufacturing

	Scenarios 1 & 2	**Scenario 3**	**Scenario 4**
Output	**$303,500,000**	**$1,779,632,375**	**$4,156,146,628**
Direct GDP	$84,100,510	$499,396,012	$1,158,129,532
Indirect GDP	$73,220,323	$458,677,050	$1,032,938,786
Induced GDP	$49,321,179	$292,132,322	$678,426,752
Total GDP	$206,642,012	$1,250,205,384	$2,869,495,070
Direct Employment	750	4,347	10,216
Indirect Employment	581	3,625	8,184
Induced Employment	381	2,254	5,235
Total Employment	1,712	10,227	23,635

5.5 - Battery Cell Production

5.5.1 - Overview

Cell production is the first stage in the three-stage process of EV battery manufacturing. Battery cells are units that combine positive and negative collectors, separator material, and electrolyte. There are several different types of battery cells, often distinguished by their shape (e.g. cylindrical, prismatic, and rectangular). Compared to the other stages of EV battery production (module manufacturing and pack assembly), cell production has the greatest economic impact.

Cell manufacturing often occurs on a large scale. It is also common that other activities, such as module manufacturing, occur alongside. Cell manufacturing is highly sought after by government economic development and investment attraction organizations, as such facilities are considered to be catalysts for EV assembly and other value-added activities. Similar to ICEV powertrain module manufacturing facilities, one cell production facility may serve several EV assembly plants in a production network.[80] Cell manufacturing facilities can increase output efficiently when operating at scale, without relying on equivalent increases in employment or capital expenditures, making them a desirable investment.

The North American EV battery cell manufacturing facilities that are currently operating or that have been announced and have a confirmed plant location will have the capacity to supply more than 500 Gigawatt hours (GWh) of battery capacity annually by 2030 (Appendix VI). If realized, this capacity is sufficient to satisfy the entire North American market even under the most ambitious scenarios (in our case, the most ambitious scenario features combined annual production in Canada and the United States of 5.6 million BEVs and 1.9 million PHEVs with a total capacity of 407.7 GWh). For this reason, additional battery cell manufacturing investments are scarce and in high demand.

At the time of writing, the world's 10 largest battery manufacturers are headquartered in Asia. The majority of large-scale North American EV battery manufacturing facilities are taking the form of partnerships between these companies (e.g. LG, Panasonic) and automakers of all nationalities. These partnerships are designed to help automakers leverage the expertise and resources of existing battery manufacturers.

5.5.2 - Canada's Current Position

The recently announced Stellantis and LG Energy Solutions investment in Windsor, Ontario is Canada's first large-scale battery cell manufacturing facility.[81] This facility is anticipated to have the capacity to produce 45 GWh annually and employ 2,500 people. In addition to this facility,

[80] Klier, T. and J. Rubenstein (2021) "ICE Age Geography: Powertrain Sourcing in Europe and North America." *International Journal of Automotive Technology and Management*, 21(4): 322-342

[81] Stellantis (2022), 'Stellantis and LG Energy Solution to Invest Over $5 Billion CAD in Joint Venture for First Large Scale Lithium-Ion Battery Production Plant in Canada', https://www.stellantis.com/en/news/press-releases/2022/march/stellantis-and-lg-energy-solution-to-invest-over-5-billion-cad-in-joint-venture-for-first-large-scale-lithium-Ion-battery-production-plant-in-canada

the UK-based Britishvolt and the Ontario-based StromCore/StromVolt have announced intentions to manufacture EV battery cells in Québec. These potential investments, however, are in early stages of development and have no clear timeline. Other companies active in this space include Blue Solutions and VoltaXplore, which intends to build a graphene-based anode and cell demonstration facility in Montréal.

Attracting EV battery cell manufacturing to any jurisdiction depends on decisions made by automakers. It also depends on geopolitical factors such as trade agreements and global politics. Given its close proximity to the United States, and the integrated nature of the North American automotive industry, Canada's position within the continental and global EV battery supply chain will be closely related to decisions made stateside. That said, battery cell manufacturing facilities in both Canada and the United States will be able to supply EV assembly plants in both countries.

5.5.3 - Potential Economic Impact

There are substantial economic benefits associated with cell manufacturing. This is due to the size and scale at which cell manufacturing facilities operate, and to the high value of EV battery cells. Table 5.5.1 summarizes the potential economic benefits associated with these activities. It shows that even in a baseline scenario with no further investment, the Stellantis-LG facility will make substantial contributions to Canada's economy. The Trillium Network model estimates that this plant alone will directly contribute $1.5 billion annually to Canadian GDP, more than $4 billion to GDP when indirect and induced activities are considered, and support 12,204 jobs across the entire economy.

If Canada is able to maintain the momentum that has been created recently and attract another similarly-sized EV battery cell manufacturing facility (doubling capacity to 90 GWh), contributions to GDP and employment will increase considerably. Scenario 3 reflects such a situation. Scenario 4 goes even further, assuming that both Britishvolt and StromVolt's facilities will be online and operating at full capacity in 2030. These facilities would add 70 GWh of annual production capacity, for a total of 160 GWh across four facilities. In Scenario 4, EV battery cell manufacturing would directly contribute more than $4.8 billion annually to GDP and directly employ 8,572 persons. These contributions are considerably higher when indirect and induced activities are considered.

Table 5.5.1 - Potential Economic Impact of Cell Manufacturing

	Scenarios 1 & 2	Scenario 3	Scenario 4
Output	**$4,626,826,658**	**$8,408,280,827**	**$15,020,092,604**
Direct GDP	$1,492,073,938	$2,711,529,437	$4,843,727,760
Indirect GDP	$1,963,288,348	$3,567,862,164	$6,373,433,666
Induced GDP	$643,733,924	$1,169,850,528	$2,089,756,947
Total GDP	$4,099,096,210	$7,449,242,129	$13,306,918,373
Direct Employment	2,640	4,798	8,572
Indirect Employment	6,421	11,670	20,846
Induced Employment	3,142	5,710	10,199
Total Employment	12,204	22,178	39,617

5.6 - Battery Module Production

5.6.1 - Overview

Module production is the second of three stages in EV battery manufacturing. A battery module is a hard metallic enclosure that combines multiple battery cells. The cells are connected in series or in parallel to achieve a specific voltage output. An electronic voltage regulator may also be included to ensure that each module produces uniform and constant output.

Module manufacturing commonly occurs in the same facility where battery cells are produced. It may also take place in the same facility where battery packs are assembled. There are very few facilities that manufacture EV battery modules exclusively. Module manufacturing investments are therefore closely related to battery cell manufacturing or battery pack assembly investments (which are themselves closely associated with EV assembly).

5.6.2 - Canada’s Current Position

Blue Solutions currently manufactures battery modules for MHDVs in Boucherville, Québec. Stellantis and LG will manufacture battery modules at their battery cell production facility in Windsor, and Lion Electric plans to manufacture modules alongside pack assembly operations in Mirabel, Québec. A small number of Canadian companies manufacture battery modules for off-road or industrial applications (e.g. Stromcore in Mississauga, Ontario).

5.6.3 - Potential Economic Impact

In each scenario we assume that every EV assembled in Canada will use Canadian-made battery packs and modules. This is due to the propensity to manufacture modules and packs in close proximity to assembly plants. For this reason, the potential economic impacts associated with battery module manufacturing should be considered as the upper boundaries for domestic production. The economic impacts of battery module manufacturing are relatively low when compared to other nodes of the EV battery supply chain. Export opportunities may exist, although they are not likely to be significant on their own. Table 5.6.1 summarizes the potential economic impact of EV battery module manufacturing.

Table 5.6.1 - Potential Economic Impact of Battery Module Manufacturing

	Scenario 1	**Scenarios 2 & 3** [82]	**Scenario 4**
Output	$509,848,200	$1,201,576,504	$1,811,630,143
Direct GDP	$144,581,953	$340,741,182	$513,739,237
Indirect GDP	$144,074,698	$339,545,715	$511,936,819
Induced GDP	$90,287,689	$212,784,053	$320,816,862
Total GDP	$378,944,340	$893,070,950	$1,346,492,918
Direct Employment	271	422	528
Indirect Employment	213	333	416
Induced Employment	102	159	198
Total Employment	585	914	1,142

5.7 - Battery Pack Assembly

5.7.1 - Overview

Pack assembly is the third and final stage of EV battery production prior to integration into an EV. A battery pack is a rectangular metallic enclosure that combines battery modules, thermal management systems, and power management systems. The thermal and power management systems regulate output and temperature, preventing surges and overheating.

[82] Note that unlike in the previous nodes where scenarios 1 and 2 are grouped together, here scenarios 2 and 3 are grouped. This is because module production, pack production and vehicle production assumptions are identical for scenarios 2 and 3. In contrast, in other nodes, assumptions are identical for scenarios 1 and 2.

The large dimensions and weight of a battery pack limit its mobility. Battery pack assembly therefore occurs in close proximity to vehicle assembly facilities. In many cases pack assembly occurs on-site. Investments in pack assembly are almost always directly associated with investments in EV assembly, especially in the case of LDVs. Attracting more battery pack assembly investment therefore depends on securing EV investment mandates. Export opportunities are limited.

5.7.2 - Canada's Current Position

Battery pack assembly is currently limited in Canada. This is because Canada does not yet assemble a substantial number of EVs. Only three facilities in Canada currently assemble or have confirmed they will assemble battery packs for on-road EVs: Lion Electric (Mirabel, Québec), Blue Solutions (Boucherville, Québec), and Ford (Oakville, Ontario). It is likely that Stellantis and General Motors will assemble battery packs as their Canadian EV assembly footprint grows in the near future.

5.7.3 - Potential Economic Impact

The potential economic impact of battery pack assembly is closely related to Canadian EV assembly projections detailed in Appendix III. We assume all Canadian-made EVs will use Canadian-assembled battery packs. It is, however, possible that the battery packs integrated into MHDVs or other EVs produced in low volumes will be imported. Table 5.7.1 summarizes the potential economic benefits associated with battery pack assembly.

Table 5.7.1 - Potential Economic Impact of Battery Pack Assembly

	Scenario 1	**Scenarios 2 & 3**[83]	**Scenario 4**
Output	$647,376,517	$1,469,784,227	$2,163,300,736
Direct GDP	$183,582,018	$416,799,108	$613,465,433
Indirect GDP	$182,937,934	$415,336,797	$611,313,132
Induced GDP	$114,642,221	$260,280,259	$383,093,291
Total GDP	$481,162,173	$1,092,416,164	$1,607,871,856
Direct Employment	248	386	481
Indirect Employment	195	304	379
Induced Employment	93	145	181
Total Employment	536	836	1,041

[83] Please note that unlike in the previous nodes where scenarios 1 and 2 are grouped together, here scenarios 2 and 3 are grouped. This is because module production, pack production and vehicle production assumptions are identical for scenarios 2 and 3. In contrast, in other nodes, assumptions are identical for scenarios 1 and 2.

5.8 - EV Assembly

5.8.1 - Overview

Vehicle assembly has long been critical to Canada's economy. In 2019, LDV assembly plants generated $56.8 billion of output,[84] directly contributed $5.8 billion to GDP,[85] and employed 36,360 persons in Ontario.[86] The industry was also responsible for 9.3 per cent of Canada's total exports in 2019, with $55.4 billion worth of vehicles–shipped almost entirely to the United States.[87] MHDV manufacturing generated an additional $4.5 billion of output,[88] directly contributed $800 million to GDP,[89] and directly employed 7,815 persons across Canada (primarily in Québec and Manitoba).[90] MHDV manufacturing accounted for $3.6 billion in exports, almost all of which were destined for the United States.[91]

Vehicle assembly activities serve as catalysts for further activities along the automotive and battery supply chain. They are also important sources of R&D and process innovation. The multiplier effects of vehicle assembly are very high. Research from 2018 suggests that every job in an LDV assembly plant creates six jobs elsewhere in Canada's economy.[92] This is due partly to the relatively high average annual earnings of vehicle assembly employees, which in 2021 were $76,977, or 31 per cent more than the average for all Canadians.[93] It is also due to their high rates of output and productivity when operating at scale and the expansive automotive supply chain. These multiplier effects have, however, decreased over the past decade as the companies that assemble vehicles in Canada rely increasingly on imported powertrain and propulsion systems.

The North American vehicle assembly industry and its related production networks are highly integrated. The automotive production network in the Great Lakes states and Ontario is the largest in the world. Since the early 1990s, however, Mexico and the southern United States have been the recipients of an increasing number of vehicle assembly investments. As a result, existing vehicle assembly plants in the Great Lakes states and Ontario have faced considerable competition for vehicle production mandates. Ontario is disadvantaged vis-a-vis Michigan (and other Great Lakes states) as no automakers are headquartered in the province. Production mandates are generally renewed every five to seven years, which has led to considerable uncertainty regarding the future of Canada's vehicle assembly industry over the past decade.

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[84] Statistics Canada Symmetric Input-Output Tables, 2019
[85] Statistics Canada Table 36-10-0402-01 (formerly CANSIM 379-0030)
[86] Statistics Canada Table 36-10-0480-01 (formerly CANSIM 383-0033)
[87] ISED Trade Data Online; https://www.ic.gc.ca/eic/site/tdo-dcd.nsf/eng/home
[88] Statistics Canada Symmetric Input-Output Tables, 2019
[89] Statistics Canada Table 36-10-0402-01 (formerly CANSIM 379-0030)
[90] Statistics Canada Table 36-10-0480-01 (formerly CANSIM 383-0033)
[91] ISED Trade Data Online; https://www.ic.gc.ca/eic/site/tdo-dcd.nsf/eng/home
[92] Tanguay, R. (2018) Drive to Win: Automotive Advisor Report. http://capcinfo.ca/images/PDF/CAPC_Automotive%20Report-en.pdf
[93] Statistics Canada Table 14-10-0204-01 (formerly CANSIM 281-0027)

5.8.2 - Canada's Current Position

Canada's annual vehicle production has decreased consistently over the past two decades. During this time, five LDV assembly plants closed while only one opened. Figure 5.8.1 illustrates the number of vehicles produced in Canada between 1999 and 2021. In 1999, only four countries produced more vehicles than Canada. In 2020, 11 countries produced more, and in 2021, 14 did so. It should be noted, however, that the relatively low levels of production in Canada were due in large part to the COVID-19 pandemic and a global shortage of microchips. Over the same time, Japan-based automakers (Toyota and Honda) have supplanted Detroit-based automakers (Ford, General Motors, and Stellantis) as the leading vehicle producers in Canada.[94]

There are a number of reasons for Canada's diminished position within the global automotive industry. This includes increased automaker investments in both low-cost jurisdictions (e.g. Mexico, East-Central Europe) and near company headquarters in the United States, Japan, Germany, and South Korea. This subject is explored in more detail elsewhere.[95]

Figure 5.8.1 - Canadian Motor Vehicle Production (Units), 1999-2021

Ontario is currently home to 10 LDV assembly plants operated by five automakers (Table 5.8.1). Several currently assemble hybrid vehicles, and some plan to assemble EVs in the near future. Canada is also home to several MHDV manufacturers (Table 5.8.2). They are located in three provinces. Most produce hybrid or EV models.

[94] Sweeney, B. (2020) 'Canada's Automotive Industry: A Decade in Review.' Trillium Network for Advanced Manufacturing. https://trilliummfg.ca/wp-content/uploads/2020/05/TrilliumReport_AutoIndustry-DecadeInReview-May2020_2A.pdf

[95] Mordue, G. and B. Sweeney (2019) 'Neither Core nor Periphery: The Search for Competitive Advanced in the Automotive Semi-Periphery,' *Growth and Change*, 51(1): 34-57.

Table 5.8.1 - Ontario Light-Duty Vehicle Assembly Plants

Company	Plant	Location	Hybrid	BEV
Ford	Oakville Assembly	Oakville	No	Planned
General Motors	Oshawa Assembly	Oshawa	No	No
General Motors	CAMI	Ingersoll	No	Planned
Honda	Alliston Car	Alliston	Planned	No
Honda	Alliston Truck	Alliston	Planned	No
Stellantis	Brampton Assembly	Brampton	TBD	TBD
Stellantis	Windsor Assembly	Windsor	Yes	TBD
Toyota	South	Cambridge	Yes	No
Toyota	North	Cambridge	Yes	No
Toyota	West	Woodstock	Yes	No

Table 5.8.2 - Canada Medium- and Heavy-Duty Vehicle Assembly Plants

Company	Location	Type	Final Assembly	Hybrid	BEV
BYD	Newmarket, ON	Bus	Yes	No	Yes
Hino Motors	Woodstock, ON	Medium	Yes	No	No
Lion Electric	Saint-Jerome, QC	Bus	Yes	Yes	Yes
MCI	Winnipeg, MB	Bus	Yes	Yes	Yes
New Flyer	Winnipeg, MB	Bus	No	Yes	Yes
Nova Bus	St. Eustache, QC	Bus	Yes	Yes	Yes
PACCAR	Ste. Therese, QC	Heavy	Yes	No	No
Prevost	Sainte-Claire, QC	Bus	Yes	No	Planned

Developing an EV battery supply chain represents an opportunity to retain much of Canada's existing vehicle assembly footprint and jobs that have come under threat recently, while even gaining back some of what has been lost. Initial investments to refurbish Ford, General Motors, and Stellantis assembly plants so that they can produce EVs represent an important first step in rebuilding and modernizing Canada’s vehicle assembly industry. Doing so creates high-value anchors that can be leveraged to attract further investment across the EV battery supply chain.

5.8.3 - Potential Economic Benefits

The economic benefits associated with EV assembly are the largest of any node in the EV battery supply chain. Table 5.8.3 summarizes the economic impact of electrified LDV assembly. Table 5.8.4 summarizes the economic impact of electrified MHDV assembly. Table 5.8.5 summarizes the total potential economic impact of EV assembly including both LDVs and MHDVs. These economic impacts rely on the projections detailed in Appendix III, which are themselves based on historic Canadian production-to-sales ratios and new EV sales targets.

In Scenario 1, electrified LDV assembly directly contributes $2.1 billion annually to GDP and directly employs 10,005 persons. These contributions to GDP increase to $6.2 billion and employment increases to 43,222 when indirect and induced activities are considered. In the same scenario, electrified MHDV assembly directly contributes $94 million annually to GDP and directly employs 774 persons. These contributions to GDP increase to $237 million and employment increases to 1,906 persons when indirect and induced activities are considered.

In the more ambitious projects in Scenarios 2 and 3, which appear more realistic at the time of writing than only a few months ago, electrified LDV assembly directly contributes nearly $5 billion annually to GDP and directly employs 24,011 persons. These contributions to GDP increase to $14.9 billion and employment increases to 103,722 when indirect and induced activities are considered. In the same scenario, electrified MHDV assembly directly contributes $327 million annually to GDP and directly employs 2,708 persons. These contributions to GDP increase to $829 million and employment increases to 6,670 persons when indirect and induced activities are considered.

In the extremely optimistic Scenario 4, in which 90% of Canada's existing vehicle assembly industry has been electrified, the economic impacts are substantial. In fact, they are larger than those associated with a primarily ICEV-focused Canadian vehicle assembly industry in 2016. In this scenario, electrified LDV assembly directly contributes nearly $7.4 billion annually to GDP and directly employs 36,017 persons. These contributions to GDP increase to $22.3 billion and employment increases to 155,598 when indirect and induced activities are considered. In the same scenarios, electrified MHDV assembly directly contributes $327 million annually to GDP and directly employs 2,708 persons. These contributions to GDP increase to $829 million and employment increases to 6,670 persons when indirect and induced activities are considered.

While substantial, it is important to note that these contributions to GDP and employment are most likely to replace existing employment in Canadian vehicle assembly plants. The transition to EVs is not anticipated to lead to net increases in the economic benefits associated with vehicle assembly. In other words, EVs will help Canada to sustain, rather than grow, its vehicle assembly industry. It is also anticipated that Canada will continue to produce substantial amounts of ICEVs and mild hybrid vehicles in 2030. This is reflected in Scenarios 1, 2, and 3.

It is also important to note that EV assembly creates substantial activity in non-battery-related supply chain activities. For example, and like ICEVs, EVs will require seats, windshields, body panels, airbags, frames, body panels, structural components, and interior trim (among hundreds of other parts and components). The economic impact of these activities, none of which are associated with EV batteries or ICEV propulsion systems, is captured primarily in the indirect contributions to GDP and indirect employment.

Table 5.8.3 - Potential Economic Impact of EV Assembly (LDVs)

	Scenario 1	Scenarios 2 & 3[96]	Scenario 4
Output	$15,638,789,528	$37,533,094,868	$56,299,642,302
Direct GDP	$2,065,425,687	$4,957,021,649	$7,435,532,474
Indirect GDP	$2,811,688,120	$6,748,051,489	$10,122,077,233
Induced GDP	$1,315,239,858	$3,156,575,660	$4,734,863,490
Total GDP	$6,192,353,666	$14,861,648,798	$22,292,473,197
Direct Employment	10,005	24,011	36,017
Indirect Employment	23,068	55,363	83,044
Induced Employment	10,149	24,358	36,537
Total Employment	43,222	103,732	155,598

Table 5.8.4 - Potential Economic Impact of EV Assembly (MHDVs)

	Scenario 1	Scenarios 2 & 3[97]	Scenario 4
Output	$444,334,143	$1,555,169,502	$1,555,169,502
Direct GDP	$93,556,343	$327,447,200	$327,447,200
Indirect GDP	$87,950,971	$307,828,398	$307,828,398
Induced GDP	$55,326,830	$193,643,906	$193,643,906
Total GDP	$236,834,144	$828,919,504	$828,919,504
Direct Employment	774	2,708	2,708
Indirect Employment	705	2,468	2,468
Induced Employment	427	1,494	1,494
Total Employment	1,906	6,670	6,670

[96] Unlike in the previous nodes where scenarios 1 and 2 are grouped together, here scenarios 2 and 3 are grouped. This is because module production, pack production and vehicle production assumptions are identical for scenarios 2 and 3. In contrast, in other nodes, assumptions are identical for scenarios 1 and 2.

[97] See previous footnote.

Table 5.8.5 - Potential Economic Impact of EV Assembly (Total)

	Scenario 1	Scenarios 2 & 3	Scenario 4
Output	$16,083,123,672	$39,088,264,370	$57,854,811,804
Direct GDP	$2,158,982,030	$5,284,468,850	$7,762,979,674
Indirect GDP	$2,899,639,091	$7,055,879,887	$10,429,905,631
Induced GDP	$1,370,566,689	$3,350,219,566	$4,928,507,396
Total GDP	$6,429,187,810	$15,690,568,302	$23,121,392,701
Direct Employment	10,778	26,719	38,725
Indirect Employment	23,773	57,830	85,512
Induced Employment	10,576	25,852	38,032
Total Employment	45,127	110,402	162,268

5.9 - Battery Recycling

5.9.1 - Overview

Battery recycling refers to removing batteries from end-of-life vehicles and subsequently processing those batteries to recover materials that can be refined and reused. It also refers to the process of recovering materials from cell production scrap and from faulty batteries. Recycling helps reduce the overall environmental footprint of EV batteries and represents an important source of materials to reduce the reliance on mining.

In the case of end-of-life batteries, the first step involves removing the battery from the vehicle. The second step involves disassembling the various components and 'shredding' and separating different materials. One of the products of this process is referred to as 'black mass', which is an amalgam of valuable battery minerals. The third step involves a chemical conversion process that separates different battery materials (e.g. lithium, nickel, cobalt). Material recovery rates associated with this process have improved considerably – from 50 to 90 per cent according to some estimates – in recent years thanks to extensive R&D and commercialization activities.[98]

A number of specialized recycling companies have emerged as demand for recovery services and battery materials is expected to increase. Some of these companies have attracted the attention of large investors. For example, Ontario-based Li-Cycle recently received a $100

[98] Buchanan, E. (2021) 'Recycling batteries a critical part of Canada's need for a "secure supply of raw materials" say experts,' https://electricautonomy.ca/2021/07/12/ev-battery-recycling-supply-chain/

million investment from Koch Strategic Platforms.[99] Other established chemical and metallurgical manufacturers, including Stelco and Glencore, have also shown interest in EV battery recycling.[100] While specialized facilities are likely to emerge, it is anticipated that most recycling activities will occur in or near battery material and cell manufacturing plants.

EV battery recycling capacity is expected to increase alongside battery production and EV sales over the next three decades. Our estimates, which focus on 2030, do not reflect the growth potential of this industry, which may not be realized until 2040. The UK-based Advanced Propulsion Centre estimates that battery recycling capacity will need to increase eightfold between 2030 and 2040 to meet demand in that country.[101]

Government policies play a key role in supporting the EV battery recycling industry. Whether through producer responsibility regulations or directives that require a certain amount of recycled content in new EV batteries, policies can help guide the industry's trajectory. For example, the EU is developing a regulatory framework that will require certain amounts of recycled cobalt, lithium, and nickel in new EV batteries beginning in 2027.[102] While these policies tend to focus on end-of-life batteries, battery material and cell manufacturers are anticipated to be more interested in recycling production scrap in the near term. The recently-announced partnership between Ultium Cells (a General Motors-LG joint venture) and Li-Cycle provides an example of how recyclers may enter contracts with cell manufacturers or automakers to secure feedstock for their operations.[103]

5.9.2 - Canada's Current Position

Our research identified nine EV battery recycling facilities in Canada that are currently operational or anticipated to be online in 2030. Three focus primarily on 'shredding' while the others are focused on materials conversion. Li-Cycle, Lithion Recycling, and Retriev Technologies are primarily involved in shredding. Electra Battery Materials, Stelco, Umicore, BASF, and General Motors-POSCO are more likely to be involved in materials conversion. We estimate that when combined these facilities will have the capacity to shred 17,500 tonnes of EV batteries and process 65,250 tonnes of black mass annually.

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[99] Tan, G. (2021) 'Koch Arm Agrees to $100 Million Bet on Li-Cycle Holdings', https://www.bloomberg.com/news/articles/2021-09-29/koch-arm-agrees-100-million-bet-on-battery-recycler-li-cycle

[100] Sarabia, L. (2021) 'Stelco and Primobius announce joint North American battery recycling venture', https://electricautonomy.ca/2021/06/03/stelco-primobius-battery-recycling/

[101] Advanced Propulsion Centre UK (2021) 'UK Automotive Strategy Planning 2021', https://www.apcuk.co.uk/uk-battery-waste-recycling/

[102] European Parliamentary Research Service (2022) 'A new EU regulatory framework for batteries', https://www.europarl.europa.eu/RegData/etudes/ATAG/2022/729285/EPRS_ATA(2022)729285_EN.pdf

[103] General Motors (2021) 'Ultium Cells LLC and Li-Cycle Collaborate to Expand Recycling in North America', https://plants.gm.com/media/us/en/gm/home.detail.html/content/Pages/news/us/en/2021/may/0511-ultium.html

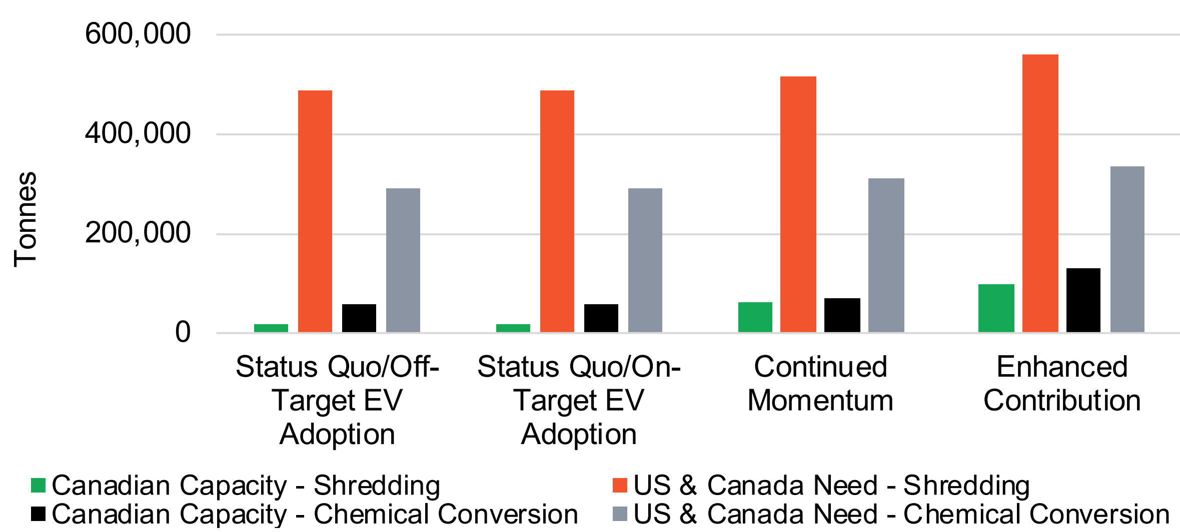
5.9.3 - Potential Economic Impact

Table 5.9.1 illustrates the potential economic impact associated with EV battery recycling. Projections in Scenarios 3 and 4 are partly based on market share assumptions (Figure 5.9.1). As noted above, these contributions are anticipated to increase substantially through the 2030s as battery production and EV adoption accelerate.

Table 5.9.1 - Potential Economic Impact of EV Battery Recycling

	Scenarios 1 & 2	Scenario 3	Scenario 4
Output	$324,731,519	$449,395,119	$788,496,054
Direct GDP	$109,475,251	$162,110,992	$281,340,186
Indirect GDP	$81,188,474	$115,378,028	$201,557,470
Induced GDP	$37,861,426	$58,815,100	$101,322,535
Total GDP	$228,525,151	$336,304,120	$584,220,191
Direct Employment	269	560	929
Indirect Employment	614	885	1,543
Induced Employment	292	454	782
Total Employment	1,176	1,900	3,254

Figure 5.9.1 - Estimated Canadian EV Battery Recycling Capacity and US & Canada Demand [104]



[104] Shedding capacity is provided in tonnes of lithium ion batteries and chemical conversion in tonnes of black mass.

SECTION 6: CANADA'S COMPETITIVE ADVANTAGES AND VALUE PROPOSITION

6.1 - Overview

Canada features unique assets and competitive advantages related to the EV battery supply chain. These include access to international markets, access to critical minerals, a skilled and talented workforce, a comprehensive manufacturing ecosystem, supportive public policies, environmental and regulatory frameworks, clean energy, and R&D and innovation. This combination of competitive advantages offers value to a diverse range of stakeholders.

This report identifies and quantifies the potential economic impact of a Canadian EV battery supply chain. Such a supply chain could result in considerable contributions to GDP, employment, government revenues, and overall prosperity. To attract further investment, however, it is absolutely critical that governments at all levels, industry stakeholders, and other organizations and partners mandated to support the EV battery supply chain coordinate closely to develop and communicate Canada's value proposition.

This section examines how Canada's unique assets and competitive advantages offer value to private sector stakeholders across the supply chain and in government. The section begins by identifying assets and competitive advantages that are broader in scope and provide value to stakeholders across the EV battery supply chain. It then refines its analysis to focus more specifically on the value provided to stakeholders that operate within particular nodes of the supply chain. It also summarizes some of the potential benefits for governments and citizens, specifically in terms of revenues.

6.2 - Competitive Advantages and Value Proposition for Companies and Investors

Our analysis identifies eight broad competitive advantages associated with Canada's EV supply chain:

1. Access to international markets;
2. Access to critical minerals;
3. Political stability;
4. A skilled and talented workforce;
5. A comprehensive manufacturing ecosystem;
6. Supportive public policies;
7. Robust environmental and regulatory frameworks;
8. Clean energy, and
9. R&D and innovation.

These competitive advantages are important components of the value proposition related to the EV battery supply chain.

Access to international markets. Canada is currently a signatory to 15 international trade agreements. These agreements provide companies operating in Canada with preferential access to more than 1.5 billion customers across 51 countries, including the United States, Japan, the EU, South Korea, and Australia. The USMCA alone offers direct foreign investors virtually tariff-free access to the United States and Mexico, which together represent 500 million potential customers. In the context of the USMCA's regional value and content origin requirements, Canada offers companies in the EV battery supply chain a gateway to the lucrative U.S. market for assembled EVs, EV battery-related products, and other EV technologies.

Access to critical minerals. Canada is the only country in the western hemisphere with known reserves of all the minerals necessary to manufacture EV batteries. Establishing secure sources of such materials has become increasingly important for Canada and other trading partners in light of recent supply chain disruptions due to the COVID-19 pandemic, ongoing diplomatic concerns with China and other authoritarian countries, and the conflict in Ukraine. Canada offers EV battery suppliers and automakers a reliable and secure source of EV battery minerals and materials. Companies based in the United States, Japan, the United Kingdom, Germany, and South Korea are already investing in upstream EV battery activities and partnerships to secure access to the EV battery minerals necessary to support their manufacturing operations.

Political stability. Canada has one of the most stable democratic governments in the world. Human rights abuses and corruption are not common in Canada. At a time when democratically-governed countries—many of which are important trading partners for Canada—are reconsidering their relationship with countries with authoritarian governments, and when unprovoked war has created substantial economic unrest and uncertainty for huge portions of the world's population, Canada's reputation for political stability offers an important advantage.

A skilled and talented workforce. Canada's education system is among the best in the world. Its workforce is renowned for its literacy, numeracy, and problem-solving capabilities. Canada's population (and its labour force) is growing, with the highest projected population growth through 2050 (21 per cent) among countries located in Europe and the Americas.[105] Much of this growth is attributable to Canadian immigration policies, including those that prioritize highly-skilled and well-educated persons. This provides businesses operating in Canada with access to a diverse and growing talent pool.

A comprehensive manufacturing ecosystem. A large majority of the emerging EV battery supply chain–especially nodes 4 through 8–will eventually be located in or near existing automotive and transportation equipment manufacturing production networks in the Great Lakes states, Ontario, Québec, and Manitoba. These production networks provide existing companies and new entrants with access to capital, suppliers, corporate decision-makers, talent, and other ecosystem partners (e.g. universities) that are not available elsewhere. In addition to Canada's well-developed automotive manufacturing industry production networks in southwestern Ontario

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[105] Authors' Calculations; United Nations, Department of Economic and Social Affairs, Population Division (2019) 'World Population Prospects 2019', https://population.un.org/wpp/.

and the Greater Toronto and Hamilton Area (GTHA), EV battery supply chain investors could potentially benefit from the knowledge and expertise associated with Canada's aerospace, rail, chemical, metallurgical, and electronics manufacturing production networks. These production networks extend across the country and are especially prominent throughout Québec and Winnipeg.

Supportive public policies. Canada's federal and most provincial governments have set ambitious carbon reduction targets, many of which relate closely to economic opportunities across the EV battery supply chain. More widespread EV adoption will be necessary to meet these targets, which in turn requires that more EVs be manufactured. While a full suite of federal policies and a general EV battery strategy are still being developed, most governments in Canada have at least signaled their intention to support investments across the supply chain. Those companies considering Canada as a location for investment are likely to benefit from support for capital and operating costs, export development, infrastructure, and workforce development.

Robust environmental and regulatory frameworks. Canada has some of the world's most stringent regulations related to greenhouse gas emissions, pollution, waste management, human rights, labour practices, and business ethics. Canada continues to build frameworks to ensure that First Nations and Indigenous communities where EV battery minerals are located benefit from mineral extraction and related activities. Canada, therefore, provides considerable value to investors that value responsible ESG.

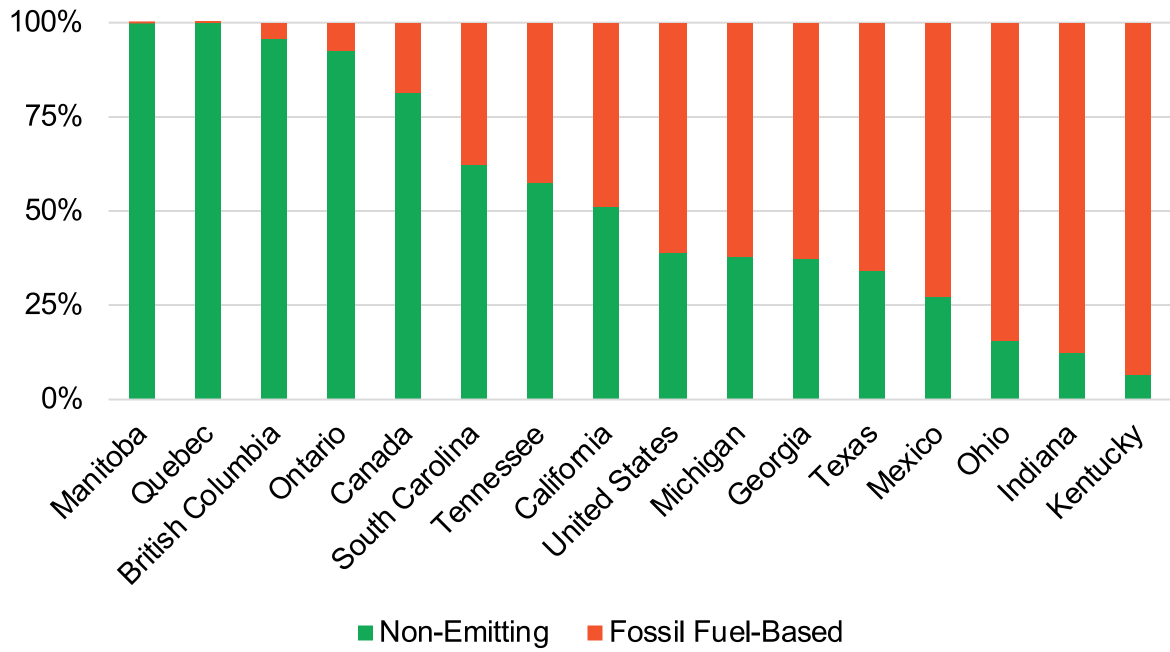
Clean energy. Reducing the carbon footprint associated with transportation requires that the electricity used to both charge and manufacture EVs is generated from low-emitting sources. If automakers are to achieve net-zero emissions in the near future, they cannot rely on supply chains powered by electricity generated from coal, gas, or other fossil fuels. Most Canadian provinces, including those where most EV battery supply chain activities are expected to be located, rely almost exclusively on electricity generated by low-emitting and renewable sources. This provides exceptional value and offers an important competitive advantage when compared to every U.S. jurisdiction with realized or anticipated EV production capacity (Figure 6.2.1). Moreover, several of the companies that recently chose to locate EV battery supply chain activities point to clean energy as an important factor in their decision to invest.[106]

R&D and Innovation. Canada is home to a large ecosystem of state-of-the-art publicly-funded and non-profit R&D and innovation centres. Many are directly involved in a number of projects and initiatives related to the EV battery supply chain. Hydro-Québec's Centre of Excellence in Transportation Electrification and Energy Storage, the University of Toronto's Electric Vehicle Research Centre, the National Research Council's Automotive and Surface Transportation Research Centre, and the Ontario Vehicle Innovation Network offer a few examples of such

[106] BASF (2022) 'BASF Acquires Site for North American Battery Materials and Recycling Expansion in Canada,' https://www.basf.com/ca/en/media/News-Releases/2022/basf-acquires-site-for-north-american-battery-materials-and-recy.html

centres. Canada's federally-funded superclusters also provide companies with support for process- and technology-based R&D and innovation.

Figure 6.2.1 - Electricity Generation by Fuel Type, Select Jurisdictions



6.3 - Node-Specific Competitive Advantages and Value Proposition for Companies and Investors

Investors within certain nodes of the EV battery supply chain may benefit from discrete competitive advantages.

For investors in the mining and mineral exploration sectors, Canada offers politically stability, a strong track record in ESG, offers reputational advantages. The Toronto Stock Exchange (TSX) and the TSX Venture Exchange, two of the world's primary listing venues for mining and mineral exploration companies, provide the necessary access to investors who need equity financing to explore and develop mineral resources. Investors can also benefit from a series of government tax incentives and public investments in transportation and communications infrastructure designed to support the development of critical mineral extraction, including EV battery minerals.

Manufacturers of battery materials, components, cells, modules and packs, and assemblers of EVs can benefit from a variety of federal and provincial government investment incentive programs. These programs generally support approximately 20 per cent of capital expenditures in both existing and greenfield facilities. These incentives often require covenants related to employment and production, which provide further benefits to communities, governments, and supply chain partners. Manufacturers can also benefit from support for export development and trade offered by the federal government through Export Development Canada (EDC) and Global Affairs Canada (GAC). These programs are administered in a consistent and transparent manner with the support of government representatives.

For battery material manufacturers specifically, Canada's location relative to EV minerals, North America's automotive production networks, and a well-developed road and rail infrastructure offers a unique advantage. This is especially the case when we consider the substantial recent disruptions to supply chains and the carbon footprint associated with shipping EV battery minerals and materials from Asia. Cross-border trade with the United States–the destination for a large majority of Canada's automotive-related exports–is well-established and facilitated by a comprehensive infrastructure.

For incumbent automakers, their existing assembly plants, workforce, parts manufacturing facilities, and supplier networks provide an important but often overlooked competitive advantage. To manufacture EVs in Canada automakers do not need to locate land, build an assembly plant, hire thousands of employees, locate a supply network, or integrate themselves into local communities. These assembly plants exist. The employees exist. The supply networks are well-developed. The infrastructure and knowledge necessary to keep plants running on a just-in-time basis in order to get vehicles to market already exists. As does ample government support for the transition from manufacturing ICEVs to EVs. The value of existing assembly plants and the broader automotive production network, which serves as the catalyst for downstream economic activities, should not be discounted. In this case, it is much easier to retain an existing manufacturer than it is to attract a new one.

6.4 - Value Proposition for Canadian Governments

While Canadian governments, and by extension, Canadian citizens, have much to gain from the EV battery supply chain, many of the benefits associated with the economic activity and employment described in this report will be concentrated in certain communities. However, when compared to the economic benefits and employment associated with the existing automotive industry, these will be much more widely dispersed across Canada, with more opportunities for northerly and First Nations communities. Moreover, the less direct but still substantial benefits that accrue from stable or increased government revenues will serve the interests of all Canadians.

Our analysis shows that in the least ambitious scenario, the economic activities associated with the EV battery supply chain will contribute $2.7 billion annually to government revenues by 2030. Note that this figure does not include corporate income taxes (which are nearly impossible to forecast accurately) nor does it include mining royalties (which are dynamic and similarly difficult to calculate). The contributions should therefore be considered to be a lower boundary.

In more ambitious scenarios, two of which appear increasingly possible, the EV battery supply chain is projected to contribute between $6.7 billion and $11 billion to government revenues annually (Tables 4.3.1 and 4.4.1). This is, of course, in addition to tens of thousands of well-paying jobs across the EV battery supply chain and even more related to indirect and induced activities.

These government revenues would presumably support social services, education, health care, and further infrastructure development across the country. They may be increasingly important to offset spending incurred during the COVID-19 pandemic. Moreover, when combined with a growing EV battery supply chain industry, they could be leveraged to foster further R&D, innovation, and growth necessary to help Canada emerge as a global leader in this space.

SECTION 7: PRIORITY OPPORTUNITIES FOR CANADA

7.1 - Overview

This report identifies three priority opportunities for Canada related to the EV battery supply chain. These opportunities reflect where Canada is best positioned to compete for investment and where the economic benefits are greatest.

The three priority opportunities are:

- EV Assembly (Node 8);
- EV Battery Cell Manufacturing (Node 5); and
- Integrated Battery Materials Manufacturing (Nodes 1, 2, 3, and 9).

Each of these opportunities can be realized in isolation. For example, Canada could develop a robust EV assembly industry with no Canadian-mined battery minerals or Canadian-made batteries. Similarly, Canada could develop a successful integrated battery materials manufacturing industry that exists purely to mine and process minerals for export.

Realizing these opportunities in isolation is not ideal. It would be unambitious. It would mean leaving value on the table. It would mean not seizing the opportunity to emerge as a global leader. The economic benefits associated with a comprehensive and integrated EV battery supply chain are far greater than those associated with isolated nodes of the supply chain. They would also serve to economically integrate more heavily urbanized regions of Canada with more northerly regions, from Windsor to Whabouchi and from Woodstock, Ontario, to Woodstock, New Brunswick.

In this case, the whole (i.e. the entire EV battery supply chain) has the potential to be much greater than the sum of the parts. Maximizing the benefits associated with each opportunity requires an overarching national strategy. That strategy should support competitive advantages that are common across the EV battery supply chain (e.g. clean energy, workforce development). It should also include policies and programs aimed at supporting node-specific investments. Furthermore, a national strategy must be led by the federal government, but should provide ample opportunity for cooperation and collaboration with provincial governments. The latter should be included throughout the development, implementation, and evaluation stages. Finally, all stakeholders should understand that this matter is urgent, but that the timelines associated with certain investments are themselves distinct.

7.2 - EV Assembly

There are three reasons why EV assembly mandates are so important. First, a large vehicle assembly industry exists in Canada. It is ambitious, but conceivable, that this entire industry could transition from assembling ICEVs to EVs exclusively sometime in the 2030s. It could do so–and produce nearly two million vehicles annually–without a new assembly plant being built.

Second, the EV assembly industry is the *sine qua non* of the EV battery supply chain–without EV assembly, there is no battery supply chain. Other activities throughout the supply chain exist to supply EV assembly plants. The goal should be to leverage existing assembly plants to incentivize additional investments across the supply chain. Third, EV assembly has the greatest economic impact in terms of direct and indirect contributions. While the EV assembly industry will hopefully create further activities elsewhere in the EV battery supply chain in Canada, it will definitely secure large portions of the existing automotive supply chain that focus on manufacturing parts, components, and materials related to the vehicle's body, chassis, interior, suspension, and braking systems.

7.3 - Battery Cell Production

Battery cell production facilities are large and highly productive. They have the greatest economic impact of any node in the EV battery supply chain save EV assembly itself. Full-scale EV battery cell production facilities create a substantial number of jobs–often in the thousands–and those jobs tend to be of a very high quality. Moreover, cell manufacturing facilities have the potential to anchor other elements of the EV battery supply chain, such as battery component (Node 4) and module (Node 6) manufacturing.

After several announcements in 2021 and 2022, it is anticipated that only a small number of additional North American EV battery cell production facilities will be announced in the near future. Each of these facilities, however, has the potential to serve as a transformative anchor investment for the community or region with which it is associated. Canada has secured one EV battery cell production facility recently. While securing such investments is a tall order, it is only necessary to secure one or two more to emerge as an important contributor in this important node of the EV battery supply chain.

7.4 - Integrated Battery Materials Manufacturing

Creating an integrated battery materials manufacturing industry, in which Canadian-mined minerals are further refined and processed into EV battery materials in nearby production facilities, is perhaps the most intriguing opportunity identified in this report. It offers an opportunity to learn from the past shortcomings of a staples-based economy. It offers an opportunity to leverage what is, when combined, Canada's most unique competitive advantage–known reserves of EV battery minerals *and* well-developed mining and automotive industries *and* a stable and democratic political environment that features strong ESG principles. No other jurisdiction in the world offers this constellation of competitive advantages.

While this opportunity may be the most intriguing, it is also the most challenging. There are few mechanisms other than vertical integration and long-term supply agreements that tether mining companies to processing facilities within the same national or sub-national jurisdictions. Some Canadian provinces have used appurtenancy agreements in the past to ensure that natural resources are further processed prior to export. Such agreements are, however, less common today than in the past and increasingly more challenging to implement in accordance with international trade regulations.

It is here, though, that the greatest opportunity to build out a large proportion of the EV battery supply chain from scratch exists. It is also an opportunity to position Canada as a leader–and the first non-Asian nation at that–in an integrated EV battery minerals and materials space. While our report focuses primarily on the economic benefits associated with the North American EV battery supply chain in 2030, there may be significant opportunities to develop other export markets for Canadian-mined and manufactured EV battery materials. The opportunities are most likely in the EU.

The opportunity to integrate recycling activities will also increase alongside the supply of recoverable EV batteries and battery materials throughout the 2020s and 2030s. Developing an integrated EV battery materials industry that relies primarily on Canadian-mined minerals, but also on recycling and imported minerals would further position Canada as a leader in this space.

SECTION 8: INVESTMENT AND SUPPORT FOR THE EV BATTERY SUPPLY CHAIN

8.1 - Overview

Investment in Canada's EV battery supply chain increased significantly in the first half of 2022. That said, it has not yet come close to reaching its full potential. Sustaining the momentum created recently requires substantial capital expenditures as well as a comprehensive suite of strategic policy and program support from governments and the private sector alike for workforce development, manufacturing, infrastructure, and trade.

This section details the extent of additional capital expenditure beyond that already committed by companies that is necessary to establish and grow an EV battery supply chain by 2030. The section also examines the public policies and programs necessary to support and grow the EV battery supply chain throughout the 2020s. This section is informed by our own analysis as well as recent reports by Natural Resources Canada (NRCan)[107] and the Battery Materials Association of Canada (BMAC).[108] Both reports present useful recommendations that we build upon.

8.2 - Capital Expenditures and Investment Incentives

Our analysis shows that Canada has attracted *at least* $1 billion of capital investment related to mining and battery materials manufacturing, $5.2 billion related to EV battery cell and module manufacturing, $6.9 billion related to EV assembly (not including investments in hybrid vehicles), and approximately $1 billion related to EV battery components and recycling (combined) since 2020. These investments are summarized in Table 8.2.1 and their economic impact is reflected in Scenarios 1 and 2.

Sustaining these investments through 2030 will require an additional $5.2 billion in capital expenditures. A large majority of these expenditures will be necessary to refurbish EV assembly facilities in the latter part of the decade. Realizing the output and economic impact associated with Scenarios 2, 3, and 4 will require between $12.2 billion and $58.4 billion in additional capital expenditures. In the more ambitious Scenarios 3 and 4, EV assembly, mining, battery cell manufacturing, and battery materials manufacturing require the most substantial capital expenditures. They also have the most substantial economic impact.

While most of these investments will be borne by the private sector, it is likely that the federal and provincial governments will provide investment incentives. These incentives have historically amounted to approximately 20 per cent of the total value of an individual investment, with the cost split equally between the federal and the respective provincial governments. Over

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[107] NRCan (2021) 'From Mines to Mobility: Seizing Opportunities for Canada in the Global Battery Value Chain,' https://www.rncanengagenrcan.ca/sites/default/files/what_we_heard_report_final_eng.pdf

[108] BMAC (2021) 'Maximizing Canada's Battery Materials Sector,' https://www.bmacanada.org/wp-content/uploads/2022/04/FINAL-Maximizing-Canadas-battery-metals-sector_BMAC-2021-Report_07-2121.pdf

time, however, the incentives have increased in value. For example, the federal and Ontario governments each committed to $295 million in support for Ford's $1.8 billion investment in Oakville, amounting to one-third of total capital expenditures.

Table 8.2.1 - Select Canadian EV Battery Supply Chain Investments, 2020-2022

Company	Location	Type	Value
Ford	Oakville, ON	EV Assembly	$1.8B
General Motors	Ingersoll, ON	EV Assembly	$1B
Stellantis	Windsor, ON	EV Assembly	$3.6B
Stellantis	Brampton, ON	EV Assembly	See Above
Nova Bus	St. Eustache, QC	EV Assembly	$185M
Prevost	Sainte-Claire, QC	EV Assembly	$84M
Lion Electric	Mirabel, QC	EV Battery	$185M
Stellantis-LG	Windsor, ON	EV Battery	$5B
General Motors-POSCO	Bécancour, QC	Battery Materials	$500M
BASF	Bécancour, QC	Battery Materials	TBD
Nouveau Monde Graphite	Bécancour, QC	Battery Materials	$15M
Electra Battery Materials	Cobalt, ON	Battery Materials	$84M
Solus Advanced Materials	Bécancour, QC	Battery Components	$450M
Magna	Chatham, ON	Battery Components	$50M
Lithion Recycling	TBD, QC	Battery Recycling	$125M

Canadian governments should therefore expect to provide a minimum of $520 million of incentives for the capital expenditures associated with Scenario 1. To realize the investments in the more ambitious scenarios they should be prepared to provide between $2.5 billion and $12 billion in investment incentives by 2030. This would be in addition to any spending associated with infrastructure, workforce development, and tax incentives. Infrastructure costs associated with mining may be particularly high. The cost of building the road network to Ontario's Ring of Fire region is alone expected to be $1.6 billion (and it will likely be much higher than that). These incentives are, however, generally consistent with those offered in Canada since the early 2000s. They are also necessary to realize the substantial government revenues associated with the EV battery supply chain, and have the potential to bring prosperity and services to remote communities in northerly regions.

8.3 - Public Policy and Government Support

Realizing further investment in Canada's EV battery supply chain requires a comprehensive suite of government policies and programs. The aversion to 'picking winners' is becoming obsolete. China has been extremely active in supporting the development of an EV industry by investing in both production and consumer adoption. The United States recently passed legislation that provides US$250 billion to support a suite of technological initiatives, including US$52 billion to develop a semiconductor industry.[109] France passed legislation in 2020 to provide US$8.8 billion to support EV manufacturing and consumer adoption.[110] This includes some of the most generous purchase incentives in the world.

If Canada is to emerge as a *leader* in this space and avoid the pitfalls of a staples economy (i.e. one that exports minimally-processed commodities and subsequently imports those commodities after they have been transformed into value-added products) it will be necessary to implement results-based policies and programs that provide both general and targeted supports to companies across the EV battery supply chain. These policies and programs should focus on the following: workforce development, technology adoption, securing EV assembly mandates, industrial land, infrastructure (including road networks and clean energy), support for industry restructuring, trade and export development, and inter-governmental collaboration and capacity-building. These findings are in many ways consistent with those in recent reports by Natural Resources Canada (NRCan),[111] the Battery Materials Association of Canada (BMAC),[112] and Next Generation Manufacturing Canada (NGen).[113]

8.3.1 - Workforce Development

Canada is home to one of the world's most diverse and well-educated talent pools. Canada's working-age population is also older than it has ever been before and acute labour shortages plagued certain industries before and during the pandemic.[114] Moreover, and unlike the rest of Canada, persons living in southern Ontario and southern Québec are remarkably reluctant to leave those areas and tend not to migrate for work in resource-based industries (i.e. mining).[115]

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[109] Franck, T. (2022) 'Senate passes $250 billion bipartisan tech and manufacturing bill aimed at countering China,' *CNBC*, https://www.cnbc.com/2021/06/08/senate-passes-bipartisan-tech-and-manufacturing-bill-aimed-at-china.html

[110] DW (2020) 'France unveils stimulus plan worth €8 billion for car industry,' https://www.dw.com/en/france-unveils-stimulus-plan-worth-8-billion-for-car-industry/a-53578294

[111] NRCan (2021) 'From Mines to Mobility: Seizing Opportunities for Canada in the Global Battery Value Chain,' https://www.rncanengagenrcan.ca/sites/default/files/what_we_heard_report_final_eng.pdf

[112] BMAC (2021) 'Maximizing Canada's Battery Materials Sector,' https://www.bmacanada.org/wp-content/uploads/2022/04/FINAL-Maximizing-Canadas-battery-metals-sector_BMAC-2021-Report_07-2121.pdf

[113] NGen (2022) 'Canadian Automotive Supplier Capability and Value Chain Analysis,' https://www.ngen.ca/hubfs/NGenEVReportMarch2022.pdf

[114] Statistics Canada (2022-04-27) 'The Daily', https://www150.statcan.gc.ca/n1/daily-quotidien/220427/dq220427a-eng.htm?HPA=1

[115] Green, D., R. Morissette, B. Sand, and I. Snoddy (2019) 'Economy-Wide Spillovers from Booms: Long Distance Commuting and the Spread of Wage Effects', *Journal of Labor Economics*, 37(S2): S643-S647.

The economic benefits associated with the EV battery chain, and any further investments, are dependent upon companies engaging a large quantity of highly skilled personnel amid historically tight labour markets. This is easier said than done.

New strategies to engage sufficient quantities of skilled workers will be necessary to both realize and capture value from investments in the EV battery supply chain. One solution may be policies and programs that support the transition of persons displaced from the oil and gas industry to the EV battery minerals and materials industries. Targeted immigration policies will also likely be valuable for all nodes of the EV battery supply chain. Governments may also consider a suite of benefits for younger workers that choose a career in this industry. These could range from tuition reimbursement to housing incentives to wage and benefit bonuses.

8.3.2 - Technology Adoption

New investments in the EV battery supply chain should feature cutting-edge production technologies that lead to high rates of productivity. In most cases, these technologies will resemble those associated with Industry 4.0. Industry 4.0 refers to digital production technologies that were first introduced in manufacturing settings but are becoming increasingly common in a variety of industries, from agriculture to healthcare. Encouraging or mandating that companies that receive government investment incentives adopt cutting-edge digital production technologies is necessary if Canada is to develop a world class EV battery supply chain. There are several government-funded initiatives, including the advanced manufacturing and AI superclusters, that provide support for the adoption of these technologies.

There are many benefits to high levels of productivity. Here we focus on two in particular. First, high productivity leads to profitability, which, in turn, allows companies to pay high wages. For many Canadians, especially younger persons, finding employment is easy. Finding meaningful employment that pays well is more difficult. Moreover, the economic benefits to governments associated with progressive income taxes and consumption increase exponentially alongside wages. Second, high rates of productivity require companies to hire fewer people. The ability to produce more with fewer employees is especially important when labour markets are tight.

8.3.3 - Securing EV Assembly Mandates

At the time of writing, there is considerable optimism regarding the future of Canada’s EV assembly industry. However, this optimism should be tempered with a certain amount of realism. Canada’s position is by no means secured in the long-term.

History shows that booms inevitably lead to busts. We expect automakers to seek to negotiate the terms under which they will continue to assemble vehicles in Canada every five or six years. (Those that are unionized may also choose to negotiate these terms through the collective bargaining process every three or four years.) Many re-investments will be one combative politician or one border protest away from unnecessarily tense negotiations with those governments. Investment incentives of 20 per cent to 30 per cent for periodic upgrades to assembly plants should be considered 'table stakes' at this point, and cancelling them would surely draw criticism from automakers. The federal and provincial governments should be prepared to maintain investment incentives. They should also be prepared to communicate their value proposition frequently, emphatically, and in *quantifiable* terms to automakers, and develop innovative programs to support EV assembly investments that go beyond basic incentives. They should at no point take for granted the presence of vehicle assembly plants–EV or otherwise–in Canada.

8.3.4 - Industrial Land

Bécancour, Québec, is emerging as a hub for EV battery materials manufacturing. More specifically, the Bécancour Waterfront Industrial Park is emerging as a hub for EV battery materials manufacturing. Without this industrial park, originally the site of a planned steel mill that never materialized, General Motors, BASF, and Solus are likely to have invested elsewhere. Similarly, the LG and Stellantis EV battery plant investment in Windsor was possible largely due to the efforts of local economic development personnel, who assembled a large parcel of land that until recently had multiple owners. Assembling this parcel required that the municipality expropriate land, a messy and mostly unwelcome process seldom taught in economic development school.

These and other greenfield investments in EV battery supply chain manufacturing activities require serviced industrial land. Investors are seldom patient when it comes to choosing a location for their facilities. Many regions of Canada, southern Ontario in particular, have shortages of serviced industrial land.[116] Much of this is due to the high demand for housing and to zoning restrictions designed to protect agricultural land. These shortages are less common throughout the United States or Mexico, where local economic development organizations have inventories of serviced industrial land in close proximity to laboursheds and production networks at the ready. If Canada hopes to compete for greenfield investments in EV battery-related activities, governments at all levels must proactively identify and develop an inventory of serviced industrial land, prioritize high value-added activities on this land (i.e. battery materials manufacturing facilities vs. warehouses full of imported consumer products), and promote this inventory to investors and site selectors.

8.3.5 - Infrastructure

Maintaining and developing infrastructure is essential to attracting further investment across the EV battery supply chain. Transportation infrastructure in the more populous regions of Canada is generally sufficient. However, significant investments in transportation infrastructure in more northerly regions are necessary if Canada is to fully leverage its EV battery minerals capabilities.

[116] Sweeney, B. and M. Cox (2021) Ontario's Industrial Land Shortage: Why it's a Problem and What We Can Do About It. https://trilliummfg.ca/wp-content/uploads/2021/12/Ontarios-Industrial-Land-Shortage_Interactive_FINAL.pdf

It is important to be realistic about the lengthy timelines associated with developing transportation networks in remote and northerly regions. Despite promises made by politicians, there is little optimism that Ontario's Ring of Fire will be fully serviced by a road network by 2030. It is imperative that governments, in partnership with investors and the First Nations communities that these road networks will also service, begin to make tangible progress on developing this infrastructure.

Maintaining and upgrading electricity infrastructure is also vital to the development of an EV battery supply chain (and to more widespread consumer adoption). This is less of a concern in Québec, where electricity generated from low-emissions sources is available in sufficient quantities at competitive prices. It is more of a concern in Ontario, where the cost of electricity has increased substantially over the past two decades, and where the lack of infrastructure has caused the province to miss out on at least one multi-billion dollar investment in 2022.[117] Projects to upgrade electricity generation and distribution infrastructure tend to be measured in decades rather than years. A comprehensive plan to generate electricity from low-emissions sources and distribute that energy effectively is necessary to realize further opportunities in the EV battery supply chain.

8.3.6 - Support for Automotive Parts Industry Restructuring

A large proportion of Canada's automotive parts industry manufactures ICEV engine, transmission, and exhaust system parts and components. Engine and transmission parts manufacturing represent approximately 32 per cent of the entire automotive parts manufacturing industry in Canada and employ more than 18,000 persons.[118] Within this category are more than 20 facilities operated by Linamar, a General Motors engine and powertrain manufacturing facility in St. Catharines, and two Ford engine manufacturing facilities in Windsor. These and other manufacturing facilities will presumably be subject to restructuring throughout the transition from ICEVs to EVs.

Linamar, General Motors, and Ford all manufacture EV-related propulsion components and systems in the United States. So do a number of other automotive parts manufacturers with operations in Canada (e.g. Magna, Aisin, ZF, Denso). Developing a strategy to support ICEV engine, transmission, and exhaust system manufacturing facilities transitioning to EV-related parts and components while at the same time incentivizing globally competitive automotive parts suppliers to manufacture these components in Canada is essential. Such a strategy may be valuable to these same companies considering tight labour markets in Canada and the United States and the high levels of skill and familiarity with the automotive industry that exist within the current workforce.

[117] CBC News (2022) 'Windsor loses our on $2.5-billion plant from LG Chem due to lack of energy supply', https://www.cbc.ca/news/canada/windsor/windsor-plant-lg-1.6448304

[118] Authors' Calculations, Statistics Canada Table 36-10-0402-01 (formerly CANSIM 379-0030) and Table 16-10-0117-01 (formerly CANSIM 301-0008)

8.3.7 - Trade and Export Development

Canada and the United States enjoy what is perhaps the most successful international trading relationship ever. The automotive industry in Canada is almost completely dependent on and integrated with the United States. Maintaining this relationship while protecting Canada's interests and competitive advantages in EV battery minerals is vital.

There may also be opportunities to develop additional export markets not considered in this study. The most promising markets will likely be in the EU, with which Canada has a trade agreement. Canada's European trading partners are probably happy to accept shipments of minimally-processed EV battery materials. Shipping minimally-processed EV battery minerals should, however, be avoided, lest Canada fall into the same staples trap that it did throughout much of the 19th and 20th centuries. Canada should endeavour to provide trading partners with access to Canadian-mined EV battery minerals only after they have undergone some substantial value-adding.

Opportunities to ship EV batteries overseas will likely be limited. This is due to automakers' preference to ship batteries by truck and locate critical nodes of their production network within a one-day drive of assembly plants. For these reasons, capturing the economic benefits of an integrated battery materials industry is critical.

8.3.8 - Incentives to Process Raw Materials in Canada

Canadian governments should explore incentives to process Canadian-mined minerals in Canada. This would require a change in a longstanding mindset related to exporting minimally-processed commodities, and may include direct government investment to build out chemical production capacity. To do otherwise is to allow foreign-owned companies to export Canada's foremost competitive advantage in the EV battery supply chain for pennies on the dollar.

8.3.9 - Inter-Governmental Collaboration and Capacity-Building

An effective national EV battery strategy will be led by the federal government. It will be comprehensive in scope and cover the entire supply chain, as well as workforce development, infrastructure, trade, and consumer adoption. It should be aligned with similar provincial initiatives, at least with those provinces that aspire to contribute and benefit from the EV battery supply chain.

The strategy should not be vague. Like ambitious federal targets related to EV sales and consumer adoption, the strategy should set targets for investment, output, and additional capital expenditures, as well as realistic timelines to achieve those targets. The strategy should aim high, with the understanding that achieving 90 per cent of an ambitious goal is more desirable than meeting or exceeding an uninspired one to save face. The strategy should also identify Canada's position and competitive advantages vis-a-vis trading partners in North America and the EU.

SECTION 9: CONCLUSION

In the space of three months, the uncertainty about Canada's role in the EV battery supply chain has been largely dispelled. Billions of dollars worth of investments in EV assembly and battery materials manufacturing, as well as plans to build Canada's first-ever battery cell manufacturing facility, show that the country will play an important role in the transition to EVs.

The most prominent questions confronting stakeholders–including manufacturers, policy-makers, and consumers–is to what extent Canada will contribute to the global EV battery supply chain. To help answer these questions, the Trillium Network for Advanced Manufacturing built a multi-industry model of the EV battery supply chain. This model was then deployed to show the economic impact by 2030 associated with four scenarios ranging from pessimistic to extremely ambitious. The most ambitious scenario shows that a comprehensive EV battery supply chain could have a greater impact than the ICEV-based automotive industry that has been a pillar of the country's economy for more than 100 years.

Canada has several competitive advantages that could help it to reach this goal. It is the only democratically-governed country in the world with known reserves of all EV battery minerals and a well-developed automotive industry. Beyond this, Canada counts a well-educated workforce, clean energy, infrastructure, and a stable political environment among its chief advantages that can help attract further investment across the EV battery supply chain.

Reaching that lofty goal is possible. But it will require billions of dollars in investment from both public and private sector stakeholders. The benefits, however, will be enormous in terms of employment, government revenues, and wealth generated to communities in urban and northerly regions alike.

This will require more than simply waiting for investors to recognize what Canada has to offer. The federal government must take the lead on developing a national strategy, a strategy that integrates provincial governments at all stages of development and implementation. The strategy should focus specifically on supporting EV assembly, EV battery cell manufacturing, and an integrated EV battery materials industry that includes mining and, eventually, recycling. To obtain full value from Canada's mineral reserves means developing the capacity to transform them into battery materials and battery cells here. It means not exporting minimally-processed minerals only to import them later as EV batteries or full-assembled EVs.

APPENDIX I: BATTERY CONTENT ASSUMPTIONS

Battery Mineral Requirements by Battery Chemistry (kg/kWh)

Battery Chemistry	Lithium in electrodes and electrolyte	Nickel in positive electrode	Cobalt in positive electrode	Manganese in positive electrode	Iron in positive electrode	Graphite in electrodes
NMC 622	0.12	0.53	0.18	0.17	0	0.89
NMC 811	0.10	0.60	0.08	0.07	0	0.88
NCA	0.10	0.67	0.13	0.00	0	0.90
LFP	0.09	0.00	0.00	0.00	0.73	1.02
LMO	0.11	0.00	0.00	1.40	0	0.85

Battery Material Requirements by Battery Chemistry (kg/kWh)

Battery Chemistry	Lithium (carbonate/ hydroxide, LCE)	Nickel (sulphate hexahydrate)	Cobalt (sulphate heptahydrate)	Manganese (HPMSM)	Phosphate (phosphoric acid)	Cathode active material	Anode material
NMC 622	0.63	2.38	0.85	0.52	0.00	1.50	0.62
NMC 811	0.53	2.69	0.36	0.22	0.00	1.27	0.62
NCA	0.54	3.01	0.60	0.00	0.00	1.38	0.63
LFP	0.50	0.00	0.00	0.00	2.56	2.06	0.71
LMO	0.56	0.00	0.00	4.37	0.00	2.36	0.60

Battery Chemistry Market Shares in 2030 [119] [120]

NMC	NCA	LFP	LMO
45%	5%	30%	20%

Recyclable Materials [121]

	Lithium	Nickel	Cobalt	Aluminum	Copper
Average (kg/kWh)	0.10	0.30	0.04	0.96	0.43
Recovery Rate	100%	100%	100%	100%	100%

[119] Morgan Stanley (2021), 'The New Oil: Investment Implications of the Global Battery Economy', Exhibit 39.

[120] We use these assumptions to estimate demand for battery minerals and materials. To estimate the economic output related to cell manufacturing , module manufacturing and pack assembly we assume that only NMC 622 type batteries are manufactured.

[121] Averages based on battery chemistry market share assumptions in the previous table.

APPENDIX II: INPUT-OUTPUT AND BATPAC MODEL ASSUMPTIONS

Input-Output Model

- NAICS Code Assignments

Industry Code	Applicable To
BS21311B	Mineral exploration
BS212230	Mining (nickel)
BS212290	Mining (cobalt, manganese)
BS21239A	Mining (lithium, graphite, phosphate)
BS325100	Battery material manufacturing (excl. anode material manufacturing); cell manufacturing; battery recycling (chemical conversion)
BS327A00	Battery material manufacturing (anode material/graphite processing)
BS336320	Battery component manufacturing (electrical/electronic)
BS336370	Battery component manufacturing (metal/composite)
BS336390	Module manufacturing, pack assembly
BS336110	LDV assembly
BS336120	MHDV assembly
BS418000	Battery recycling (shredding)

- Adjustments [122]

NAICS Code	Adjusted for	Rationale for Adjustment
BS21311B	N/A	N/A
BS212230	BS21311B	Included as part of a previous node
BS212290	BS21311B	Included as part of a previous node
BS21239A	BS21311B	Included as part of a previous node
BS325100	BS111A00, BS211110, BS211140, BS212230, BS212290, BS21239A, BS21311A, BS21311B, BS311200, BS324110, BS325100 (only in calculations for cell manufacturing), BS325200, BS331400	Unrelated industries for EV batteries or included as part of a previous node
BS327A00	BS211110, BS212310, BS212320, BS21239A	Unrelated industries for EV batteries or included as part of a previous node
BS336320	N/A	N/A
BS336370	N/A	N/A
BS336390	N/A	N/A

[122] When calculating the indirect and induced output changes resulting from activities classified under the industries listed in the first column, the related economic impact associated with the industries listed in the second column were deducted.

BS336110	BS336310, BS336350	ICEV-related industries
BS336120	BS336310, BS336350	ICEV-related industries
BS418000	N/A	N/A

- Derived Multipliers (before adjustments)[123]

	GDP Multipliers (per dollar of output)			Job Multipliers (per million dollars of output)		
NAICS Code	**Direct**	**Indirect**	**Induced**	**Direct**	**Indirect**	**Induced**
BS21311B	0.570	0.249	0.295	4.58	2.03	2.27
BS212230	0.642	0.153	0.148	1.22	1.80	1.14
BS212290	0.569	0.274	0.169	1.69	2.09	1.30
BS21239A	0.634	0.245	0.184	2.50	1.84	1.42
BS325100	0.322	0.424	0.139	0.57	2.64	1.07
BS327A00	0.403	0.349	0.207	3.97	2.77	1.60
BS336320	0.263	0.174	0.156	2.58	1.42	1.20
BS336370	0.287	0.289	0.167	2.39	2.27	1.29
BS336390	0.284	0.283	0.177	2.86	2.25	1.37
BS336110	0.132	0.199	0.089	0.64	1.61	0.69
BS336120	0.211	0.224	0.132	1.74	1.77	1.02
BS418000	0.575	0.318	0.261	5.04	2.68	2.01

BatPaC Model Parameters

- Battery-Specific Parameters

Vehicle Type	Battery Capacity (kWh)	Number of cells per module	Modules per pack	Battery Chemistry
LDV-BEV	64	12	20	NMC622-G
LDV-PHEV	15			
MHDV-BEV	330	48	40	
MHDV-PHEV	104			

[123] Please see the Methodology section for further details on these multipliers.

Other Parameters

Parameter	Value (US$)
Direct labour cost ($/hr)	25.0
Positive electrode active material	20.6
Negative electrode active material	12.5

APPENDIX III: NODE-SPECIFIC MODEL INPUTS

Node 1 - Mineral Exploration

Output Estimation [124]

Description	2014	2015	2016	2017	2018	Model Assumption
(A) Output - Mining and Quarrying, Except Oil and Gas ($ millions)	$40,333.50	$39,898.60	$37,871.20	$44,545.60	$47,840.40	N/A
(B) Output - Support Activities for Mining ($ millions)	$5,739.70	$5,561.50	$5,204.70	$5,834.50	$6,436.90	N/A
(B) divided by (A) [Mineral Exploration output as a percentage of Mining output]	14.2%	13.9%	13.7%	13.1%	13.5%	15.0%

Mineral Exploration and Deposit Appraisal Expenditure Requirement Estimation

Description	Year	Base Metals	Other Metals	Non-metals	Model Assumption (Blended)
(A) Exploration and Deposit Appraisal Spending [125]	**2020**	400	35	33	N/A
	2021	502	87	312	N/A
(B) Output [126]	**2018**	$9,859.6	$2,172.5	$14,192.6	N/A
(A) divided by (B) [Exploration and Deposit Appraisal Spending as a ratio of Mining output]	**2020 (A) / 2018 (B)**	4.1%	1.6%	0.2%	3.16% - 4.70%
	2021 (A) / 2018 (B)	5.1%	4.0%	2.2%	

[124] Authors' Calculations, Statistics Canada Table 36-10-0488-01 (formerly CANSIM 381-0031).
[125] Natural Resources Canada (2021), Canadian Mineral Exploration Information Bulletin, https://www.nrcan.gc.ca/maps-tools-and-publications/publications/minerals-mining-publications/canadian-mineral-exploration/17762.
[126] Authors' Calculations, Statistics Canada Table 36-10-0488-01 (formerly CANSIM 381-0031)

Node 2 - Mining

Commodity Price Assumptions (2030) [127]

Mineral	Mineral Prices (US$/kg)
Lithium (spodumene)	0.653
Nickel	18.43
Cobalt	40.07
Manganese (ore)	0.0056
Graphite (natural)	1.5
Phosphate (rock)	0.2

[127] World Bank (2021) 'World Bank Commodities Price Forecast (nominal US dollars)', https://thedocs.worldbank.org/en/doc/ff5bad98f52ffa2457136bbef5703ddb-0350012021/related/CMO-October-2021-forecasts.pdf.
Morgan Stanley (2021) 'The New Oil: Investment Implications of the Global Battery Economy'.

Select Mining Projects

					Included in[128]:		
Company	**Project Name / Location**	**Mineral**	**Owner's Expected Opening Year[129]**	**Annual Capacity (mt/yr)**	**Status Quo (Scenarios 1 & 2)**	**Continued Momentum (Scenario 3)**	**Enhanced Contribution (Scenario 4)**
Fortune Minerals	NWT	Cobalt	N/A	1,800		Yes	Yes
Eagle Graphite	Black Crystal	Graphite	N/A	7,500	Yes	Yes	Yes
Northern Graphite	Lac des Iles	Graphite	N/A	15,000	Yes	Yes	Yes
Northern Graphite	Bissett Creek	Graphite	2023	20,000		Yes	Yes
Nouveau Monde	Matawinie	Graphite	2025	100,000	Yes	Yes	Yes
Allkem	James Bay	Lithium	2025	321,000	Yes	Yes	Yes
Critical Elements	Rose	Lithium	2024	186,327		Yes	Yes
Nemaska Lithium	Whabouchi	Lithium	N/A	213,000		Yes	Yes
Rock Tech	Georgia Lake	Lithium	2029	93,000			Yes
Sayona	Northern Hub	Lithium	2027	200,000			Yes
Sayona	Abitibi Hub	Lithium	2023	220,000		Yes	Yes
Frontier Lithium	PAK	Lithium	2028	177,000			Yes
Manganese X Energy	Woodstock	Manganese	N/A	24,638			Yes
Canadian Manganese	Woodstock	Manganese	N/A	103,530			Yes
Flying Nickel	Minago	Nickel	2026	10,000			Yes
FPX Nickel	Baptiste	Nickel	N/A	45,000			Yes
Nion Nickel	Dumont	Nickel	N/A	50,000		Yes	Yes
Noront/Wyloo	Ring of Fire	Nickel	2028	15,500			Yes
Giga Metals	Turnagain	Nickel	N/A	33,000			Yes
Canada Nickel	Crawford	Nickel	N/A	34,000			Yes
Arianne Phosphate	Lac à Paul	Phosphate	N/A	1,400,000		Yes	Yes

128 Decisions on which projects to include in scenarios are based on TNAM's assessment of the projects. Some of the factors considered include but are not limited to: 1) acquisition of land or plant, 2) certainty of capital investment (e.g. committed or uncommitted), and 3) commencement or completion of major regulatory milestones (e.g. environmental and impact assessment processes, permitting, etc.), 4) past delays and issues with development, and 5) availability of necessary public infrastructure (e.g. roads, electricity).

129 These dates are provided by the companies and do not necessarily indicate that a project will definitely be online by the stated date.

Average Initial Capital Investment Requirement Estimation [130]

Mineral	Average Initial Capital Investment Requirement Per Tonne of Annual Capacity
Lithium (spodumene)	$1,440
Nickel[131]	$54,772
Cobalt[132]	$333,333
Manganese (ore)	$823
Graphite (natural)	$3,583
Phosphate (rock)	$899

Canadian Production Assumptions [133]

	Canadian Production (tonnes/year)		
Mineral (mt)	**Status Quo (Scenarios 1 & 2)**	**Continued Momentum (Scenario 3)**	**Enhanced Contribution (Scenario 4)**
Lithium (spodumene)	321,000	940,327	1,410,327
Nickel (primary)	-	50,000	187,500
Cobalt (primary)	-	1,800	4,100
Manganese (primary)	-	-	128,168
Graphite (natural)	122,500	142,500	142,500
Phosphate (phosphorus pentoxide)	-	142,384	220,908

130 Trillium Network's estimates based on information provided by companies on projects presented in the previous table.

131 Unlike other minerals, the annual nickel production capacity for projects listed in the previous table are in pure nickel equivalent, therefore substantially smaller than the actual ore/concentrate production. This leads to a relatively high average initial capital investment requirement.

132 Cobalt is usually mined alongside other minerals in Canada. Therefore, when expressed as a ratio of the annual production capacity for only cobalt, the initial capital investment requirement is significantly higher than those for other minerals.

133 These assumptions are informed by the company-provided information on specific projects listed in previous tables.

Node 3 - Battery Material Production

Material Price Assumptions (2030)

Material	**Material Prices (US$/kg)**
Lithium (carbonate)	8.0
Lithium (hydroxide)	9.1
Nickel sulphate	5.8
Cobalt sulphate	11.0
Manganese (HPMSM)	1.4
Phosphate (phosphoric acid)	0.65
Cathode active material	20.6
Anode active material	6.25
Electrolyte ($/L)	15

Select Battery Material Projects

					Included in[134]:		
Company	**Project Name / Location**	**Mineral**	**Planned Start of Production [135]**	**Annual Capacity (tonnes /yr)**	**Status Quo (Scenarios 1 & 2)**	**Continued Momentum (Scenario 3)**	**Enhanced Contribution (Scenario 4)**
Nouveau Monde	Phase 1	Anode material	2022	2000	Yes	Yes	Yes
Nouveau Monde	Phase 2	Anode material	2025	42,000		Yes	Yes
BASF	Bécancour	CAM	2025	100,000	Yes	Yes	Yes
GM/POSCO	Bécancour	CAM	2025	30,000	Yes	Yes	Yes
Electra Battery Materials	Material Park	Cobalt (sulphate)	2023	32,500	Yes	Yes	Yes
Fortune Minerals	Alberta	Cobalt (sulphate)	N/A	4,737		Yes	Yes
Avalon Lithium	Thunder Bay	Lithium (carbonate)	2025	20,000		Yes	Yes
Sayona	Refinery	Lithium (carbonate)	2025	55,000			Yes
Nemaska Lithium	Bécancour	Lithium (carbonate)	N/A	3,250		Yes	Yes
E3 Metals	Clearwater	Lithium (hydroxide)	2025-2026	20,000			Yes
Critical Elements	Refinery	Lithium (hydroxide)	N/A	27,000			Yes
Frontier Lithium	Refinery	Lithium (hydroxide)	2028	21,392			Yes
Nemaska Lithium	Bécancour	Lithium (hydroxide)	N/A	28,000		Yes	Yes
Manganese X Energy	Woodstock	Manganese (HP)	N/A	50,000			Yes
FPX Nickel	Refinery	Nickel (sulphate)	N/A	214,633			Yes
Electra Battery Materials	Material Park	Nickel (sulphate)	2024	268,697		Yes	Yes
Arianne Phosphate	Belledune	Phosphate (acid)	N/A	500,000			Yes

[134] Decisions on which projects to include in scenarios are based on TNAM's assessment of the projects. Some of the factors considered include but are not limited to: 1) acquisition of land or plant, 2) certainty of capital investment (e.g. committed or uncommitted), and 3) commencement or completion of major regulatory milestones (e.g. environmental and impact assessment processes, permitting, etc.), 4) past delays and issues with development, and 5) availability of necessary public infrastructure (e.g. roads, electricity).

[135] These dates are provided by the companies and do not necessarily indicate that a project will definitely be operational by the stated date.

Initial Capital Investment Requirement Estimation [136]

Mineral	Average Initial Capital Investment Requirement Per Tonne of Annual Capacity
Anode material	$13,095
CAM	$15,385
Cobalt (sulphate heptahydrate)	$2,820
Lithium (carbonate)	$25,000
Lithium (hydroxide monohydrate)	$31,022
Manganese (HPMSM)	$3,900
Nickel (sulphate hexahydrate)	$1,303
Phosphate (phosphoric acid)	$660

Node 4 - Battery Component Manufacturing

Battery Component Price Assumptions (US$/pack)

Component	LDV-BEV	LDV-PHEV	MHDV-BEV	MHDV-PHEV
Electrolyte	329.90	128.11	1,696.70	818.93
Positive current collector (aluminum foil)	84.73	23.97	256.02	91.40
Negative current collector (copper foil)	357.56	103.94	1,087.47	394.01
Separators	551.57	156.48	1,664.39	606.26
Cell hardware	165.28	136.85	844.12	457.44
Module hardware	892.14	743.11	3,618.53	1,678.34
Pack hardware	586.77	418.03	1,362.44	666.5
Battery management system	556.45	556.45	1,788.44	1,095.39
Thermal management system	40	40	40	40

[136] Trillium Network's estimates based on information provided by companies on projects presented in the previous table.

Select Battery Component Projects

Company	Location	Product	Assumed Annual Output (C$ million)
Magna	Chatham, ON	Pack hardware	70
Solus Advanced Materials	Granby, QC	Negative current collector (copper foil)	170
Can Art Aluminum Extrusion	Windsor, ON	Pack hardware	10
Dana Canada Thermal Products	Cambridge, ON	Heat exchangers	23.5
Eberspaecher Vecture	Vaughan, ON	Battery management systems	30

Node 5 - Battery Cell Production

Cell Manufacturing Assumptions (GWh/year)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Plant 1	45	45	45	45
Plant 2	-	-	45	45
Plant 3	-	-	-	60
Plant 4	-	-	-	10
Total	45	45	90	160

Node 6 & 7 - Battery Module Production and Pack Assembly

Module Manufacturing and Pack Assembly Assumptions (GWh/year)[137]

Vehicle Type	Scenario 1	Scenario 2	Scenario 3	Scenario 4
LDV-BEV	20.8	49.9	49.9	83.1
LDV-PHEV	1.6	3.9	3.9	6.5
MHDV-BEV	0.4	1.6	1.6	4.4
MHDV-PHEV	0.1	0.2	0.2	0.6

[137] We assume that all BEV/PHEVs assembled in Canada will have their modules manufactured and packs assembled in Canada. The GWh values provided in this table are derived from the number of vehicles assumed to be assembled in Canada (see next table).

Node 8 - EV Assembly

Canadian Vehicle Sales and Production Assumptions, Production-to-Sales Ratios (2030)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
New Sales (LDV - All)	2,026,885	2,026,885	2,026,885	2,026,885
New Sales (LDV - BEV)	380,041	912,098	912,098	1,368,147
New Sales (LDV - PHEV)	126,680	304,033	304,033	456,049
LDV BEV/PHEV in New Sales	**25%**	**60%**	**60%**	**90%**
LDV Production to Sales Ratio[138]	85%			
LDV BEV Production	**324,720**	**779,329**	**779,329**	**1,168,994**
LDV PHEV Production	**108,240**	**259,776**	**259,776**	**389,665**
New Sales (MHDV - All)	36,216	36,216	36,216	36,216
New Sales (MHDV - BEV)	2,535	8,873	8,873	8,873
New Sales (MHDV - PHEV)	1,086	3,803	3,803	3,803
MHDV BEV/PHEV in New Sales	**10%**	**35%**	**35%**	**35%**
MHDV Production to Sales Ratio[139]	53%			
MHDV BEV Production	**1,346**	**4,712**	**4,712**	**4,712**
MHDV PHEV Production	**577**	**2,019**	**2,019**	**2,019**

[138] Authors' Calculations, Automotive News/IHS Market. Vehicle production (available up to 2029; 2030 figures were projected using the average projected change in production between 2025-2029) and sales projections (available up to 2027; 2028-2030 figures were projected based on the average projected change in sales between 2025-2027) from Automotive News. Production-to-sales ratio is defined as the number of vehicles assembled divided by the number of vehicles sold in the same country in a given year.

[139] Authors' Calculations, International Organization of Motor Vehicle Manufacturers (OICA). Based on the historical MHDV production figures obtained from the International Organization of Motor Vehicle Manufacturers (OICA) and Trillium Network's projections for 2021-2030. Projections were based on the projected LDV production changes obtained from Autonews.com/IHS Markit. Production-to-sales ratio is defined as the number of vehicles assembled divided by the number of vehicles sold in the same country in a given year.

United States Vehicle Sales and Production Assumptions, Production-to-Sales Ratios (2030)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
New Sales (LDV - All)	16,328,991	16,328,991	16,328,991	16,328,991
New Sales (LDV - BEV)	1,959,479	4,041,425	4,041,425	6,123,372
New Sales (LDV - PHEV)	653,160	1,347,142	1,347,142	2,041,124
LDV BEV/PHEV in New Sales	**16%**	**33%**	**33%**	**50%**
LDV Production to Sales Ratio[140]	70%			
LDV BEV Production	**1,368,520**	**2,822,572**	**2,822,572**	**4,276,624**
LDV PHEV Production	**456,173**	**940,857**	**940,857**	**1,425,541**
New Sales (MHDV - All)	493,543	493,543	493,543	493,543
New Sales (MHDV - BEV)	31,093	55,277	55,277	79,460
New Sales (MHDV - PHEV)	13,326	23,690	23,690	34,054
MHDV BEV/PHEV in New Sales	**9%**	**16%**	**16%**	**23%**
MHDV Production to Sales Ratio[141]	60%			
MHDV BEV Production	**18,724**	**33,287**	**33,287**	**47,851**
MHDV PHEV Production	**8,025**	**14,266**	**14,266**	**20,507**

Node 9 - Battery Recycling

Canadian Battery Recycling Feedstock Assumptions (2030)

Feedstock	Description	Scenario 1 & 2	Scenario 3	Scenario 4
End-of-Life Batteries (kWh)[142]	N/A	3,097,154	3,097,154	3,097,154
Production scrappage (kWh)	10% of domestic production	4,500,000	9,000,000	16,000,000
Warranty recalls (kWh)	1% of new sales	229,100	555,386	946,655

[140] Authors' Calculations, Source: Automotive News/IHS Market. Vehicle production (available up to 2029; 2030 figures were projected using the average projected change in production between 2025-2029) and sales projections (available up to 2027; 2028-2030 figures were projected based on the average projected change in sales between 2025-2027) from Automotive News. Production-to-sales ratio is defined as the number of vehicles assembled divided by the number of vehicles sold in the same country in a given year.

[141] Authors' Calculations, International Organization of Motor Vehicle Manufacturers (OICA). Based on the historical MHDV production figures obtained from the International Organization of Motor Vehicle Manufacturers (OICA) and Trillium Network's projections for 2021-2030. Projections were based on the projected LDV production changes obtained from Automotive News/IHS Markit. Production-to-sales ratio is defined as the number of vehicles assembled divided by the number of vehicles sold in the same country in a given year.

[142] Based on 2020 EV sales data in Canada, obtained from Statistics Canada, available at https://www150.statcan.gc.ca/n1/daily-quotidien/210422/dq210422e-eng.htm

United States Battery Recycling Feedstock Assumptions (2030)

Feedstock	Description	Scenario 1 & 2	Scenario 3	Scenario 4
End-of-Life Batteries (kWh) [143]	N/A	38,695,658	38,695,658	38,695,658
Production scrappage (kWh) [144]	10% of domestic production	50,000,000	50,000,000	50,000,000
Warranty recalls (kWh)	1% of new sales in 2030	1,014,414	2,072,259	3,130,105

Canadian Recycling Capacity and Market Share Assumptions

	Total Demand (Canada & US)			Canadian Production			Canada's Market Share		
Recycling Category	**Scenarios 1 & 2**	**Scenario 3**	**Scenario 4**	**Scenarios 1 & 2**	**Scenario 3**	**Scenario 4**	**Scenarios 1 & 2**	**Scenario 3**	**Scenario 4**
Shredding (mt of LIB)	487,682	517,102	559,348	17,500	63,242	100,160	4%	12%	18%
Chemical Conversion (mt of black mass)	292,609	310,261	335,609	57,750	71,972	128,934	20%	23%	38%

Other Recycling Assumptions [145]

- Prices of recycled minerals / materials were assumed to be at 30% of virgin mineral / material costs. A processing cost of $117 per tonne of material was assumed. The value added from the chemical conversion process is assumed to be 30%.[146]

Processing Conversion Ratios	Value
Shredding (C$ output per tonne LIB)	1,075
Chemical Conversion (C$ output per tonne LIB)	3,178
Chemical Conversion (C$ output per tonne black mass)	5,297
Tonne LIB per GWh Battery	5,000

143 Based on the 2020 EV sales data for Canada, obtained from Statistics Canada, available at https://www150.statcan.gc.ca/n1/daily-quotidien/210422/dq210422e-eng.htm

144 U.S. battery cell production is assumed to be approximately 500 GWh/year for simplicity based on the plants detailed in Appendix VI.

145 Trillium Network's estimates based on information obtained from: https://glginsights.com/articles/the-economics-around-lithium-ion-battery-recycling-are-strong-and-growing/ and https://s27.q4cdn.com/432858399/files/doc_presentations/2022/LICY-Investor-Presentation-April-2022-v-Final-for-4.12.22-posting.pdf and https://www.apcuk.co.uk/app/uploads/2022/02/Battery-recycling-UK-Advanced-Propulsion-Centre.pdf

146 Based on the Statistics Canada GDP multiplier for BS325100 provided in Table 36-10-0594-01.

Initial Capital Expenditure Requirement Estimation

Description	**Value**
Shredding (million C$ per tonne of LIB processing capacity)	0.017
Chemical Conversion (million C$ per tonne of black mass processing capacity)	0.032

APPENDIX IV: PRODUCTION AND MARKET SHARE ASSUMPTIONS [147]

	Total Demand (Canada & US)				Canadian Production				Canada's Market Share (% of total Canada and US market)			
Mineral / Material	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Lithium (spodumene)	206,789	436,962	436,962	657,587	321,000	321,000	940,327	1,410,327	155%	73%	215%	214%
Nickel (primary)	37,781	79,835	79,835	120,145	-	-	50,000	187,500	0%	0%	63%	156%
Cobalt (primary)	5,003	10,571	10,571	15,909	-	-	1,800	3,977	0%	0%	17%	25%
Manganese (primary)	38,672	81,717	81,717	22,976	-	-	-	128,168	0%	0%	0%	104%
Graphite (natural)	114,260	241,442	241,442	363,347	122,500	122,500	142,500	142,500	107%	51%	59%	39%
Phosphate (rock)	67,382	142,384	142,384	214,275	-	-	142,384	214,275	0.0%	0.0%	100%	100%
Lithium (LCE[148])	66,044	139,557	139,557	210,020	-	-	47,890	163,075	0%	0%	34%	78%
Nickel (sulphate)	169,196	357,525	357,525	538,041	-	-	268,697	483,330	0%	0%	75%	90%
Cobalt (sulphate)	23,862	50,422	50,422	75,880	32,500	32,500	37,237	37,237	136%	64%	74%	49%
Manganese (HPMSM)	120,849	255,364	255,364	384,300	-	-	-	50,000	0%	0%	0%	13%
Phosphate (phosphoric acid)	95,578	201,964	201,964	303,936	-	-	-	303,936	0%	0%	0%	100%
Cathode active material	215,259	454,859	454,859	684,520	130,000	130,000	260,000	350,000	60%	29%	57%	51%
Anode material	79,982	169,009	169,009	254,343	2,000	2,000	44,000	63,586	3%	1%	26%	25%

[147] Values in grey cells are authors' assumptions and are independent of the projects and production capacities listed in Appendix III.
[148] LCE = lithium carbonate equivalent.

	Total Demand (Canada & US)				Canadian Output				Canada's Market Share (% of total Canada and US market)			
COMPONENTS (C$ millions)	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Electrolyte	$873.6	$1,845.9	$1,845.9	$2,777.7	$0.0	$0.0	$115.4	$347.2	0%	0%	6.25%	12.5%
Positive current collector	$211.8	$448.7	$448.7	$676.6	$0.0	$0.0	$28.0	$84.6	0%	0%	6.25%	12.5%
Negative current collector	$896.1	$1,898.6	$1,898.6	$2,862.4	$170.0	$170.0	$600.0	$600.0	19%	9%	32%	20%
Separators	$1,379.1	$2,922.0	$2,922.0	$4,505.5	$0.0	$0.0	$182.6	$550.7	0%	0%	6.25%	12.5%
Cell hardware	$491.4	$1,038.9	$1,038.9	$1,564.1	$23.5	$23.5	$64.9	$195.5	5%	2%	6.25%	12.5%
Module hardware	$2,622.2	$5,551.6	$5,551.6	$8,365.7	$0.0	$0.0	$347.0	$1,045.7	0%	0%	6.25%	12.5%
Pack hardware	$1,641.3	$3,481.4	$3,481.4	$5,253.0	$80.0	$80.0	$217.6	$656.6	5%	2%	6.25%	12.5%
Battery management system	$1,692.1	$3,585.6	$3,585.6	$5,406.7	$30.0	$30.0	$224.1	$675.8	2%	1%	6.25%	12.5%
Thermal management system	$118.9	$252.6	$252.6	$381.5	$0.0	$0.0	$15.8	$47.7	0%	0%	6.25%	12.5%

APPENDIX V: QUANTIFICATION OF GOVERNMENT REVENUES [149]

Average Annual Compensation Per Employee (Canadian Dollars)[150]

Industry	2016	2017	2018	2019	2020	Average
BS212230	121,660	122,576	124,263	131,114	142,905	128,503
BS212290	130,744	121,625	129,887	130,876	131,597	128,946
BS21239A	82,234	83,679	87,922	92,691	96,332	88,571
BS21311B	105,679	108,454	111,793	113,003	120,359	111,858
BS325100	133,610	132,213	139,650	139,160	144,381	137,803
BS327A00	70,174	71,326	74,673	75,174	78,958	74,061
BS336110	124,898	122,133	123,738	122,521	133,582	125,374
BS336120	83,092	78,912	79,879	81,857	84,257	81,599
BS336320	77,811	77,618	79,619	79,978	85,813	80,168
BS336370	84,148	84,628	86,120	85,626	90,280	86,160
BS336390	73,857	74,226	75,957	75,396	79,928	75,873
BS418000	66,218	66,912	68,342	69,974	74,578	69,205

Federal and Provincial Income Tax Bracket Assumptions [151] [152]

Federal	**Up to first $50,197**	**$50,198 to $105,430**	**$105,431 to $171,513**
	15%	20.5%	26%
Provincial	**Up to first $46,226**	**$46,227 to $92,454**	**$92,455 to $150,000**
	5.05%	9.15%	11.16%

[149] Contributions to Employment Insurance and Canada Pension Plan are assumed to be at maximum amounts as average total compensation per employee in each industry is above the applicable thresholds as per information provided at https://www.canada.ca/en/revenue-agency/services/tax/businesses/topics/payroll/payroll-deductions-contributions/employment-insurance-ei/ei-premium-rate-maximum.html and https://www.canada.ca/en/revenue-agency/services/tax/businesses/topics/payroll/payroll-deductions-contributions/canada-pension-plan-cpp/manual-calculation-cpp.html.

[150] Authors' Calculations; Statistics Canada Table 36-10-0489-01 (formerly CANSIM 383-0031) and Statistics Canada Table 36-10-0489-03.

[151] Government of Canada (2022), Federal tax rates for 2022, https://www.canada.ca/en/revenue-agency/services/tax/individuals/frequently-asked-questions-individuals/canadian-income-tax-rates-individuals-current-previous-years.html

[152] Based on the taxes applicable in the Province of Ontario, provided at https://www.canada.ca/en/revenue-agency/services/tax/individuals/frequently-asked-questions-individuals/canadian-income-tax-rates-individuals-current-previous-years.html

APPENDIX VI: NORTH AMERICA EV BATTERY CELL PLANTS

Company	City	Province/State	Country	Start of Production	Long Term Capacity (GWh)
Toyota/Toyota Tsusho	Liberty	North Carolina	United States	2025	45
Ford/SK Innovation (BlueOvalSK)	Stanton	Tennessee	United States	2025	43
Ford/SK Innovation (BlueOvalSK)	Glendale	Kentucky	United States	2025	86
SK Innovation	Commerce	Georgia	United States	2022	9.8
SK Innovation	Jackson County	Georgia	United States	2023	11.7
Tesla/Panasonic (Pilot Plant)	Fremont	California	United States	2022	10
Tesla/Panasonic	Sparks	Nevada	United States	Operational	35
Tesla/Panasonic	Austin	Texas	United States	2022	100
GM/LG Energy (Ultium)	Spring Hill	Tennessee	United States	2023	35
GM/LG Energy (Ultium)	Lordstown	Ohio	United States	2022	30
GM/LG Energy (Ultium)	Lansing	Michigan	United States	2025	50
LG Energy	Holland	Michigan	United States	Operational	40
LG Energy	Queen Creek	Arizona	United States	2024	11
AESC Envision/Nissan	Smyrna	Tennessee	United States	Operational	3
AESC Envision/Nissan	Bowling Green	Kentucky	United States	2027	30
Akasol/BorgWarner	Hazel Park	Michigan	United States	2020	2
iM3NY	Endicott	New York	United States	2022	30
Romeo Power	Los Angeles	California	United States	2018	7
Saft	Jacksonville	Florida	United States	Operational	1
Microvast	Clarksville	Tennessee	United States	2022	2
Total Capacity (US) (GWh/yr)					506.5
Stellantis/LG Energy	Windsor	Ontario	Canada	2024	45
Total Capacity (Canada) (GWh/yr)					45.0

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