FAST-CHARGING ONTARIO'S ELECTRIC VEHICLE WORKFORCE

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PREFACE

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Researched and written by Erik Henningsmoen (Research and Policy Analyst), Todd Legere (Economist and Research Analyst), Mairead Matthews (Manager, Digital Policy), Francis Okpaleke (Senior Research and Policy Analyst), and Justin Ratcliffe (Economist & Research Analyst) with generous support from Jianshi Li, Trevor Quan, and the ICTC Research & Policy team.

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Arthur Kong
Director of Project Development, NGen Canada

Cara Clairman
President and CEO, Plug'n Drive

Chad J. Yee
Director, Electric Vehicle Society (EVS)

Charlotte Argue
Sr. Manager Sustainable Mobility, Geotab Inc.

Christopher Nabeta
Executive Chairman & Founding Member, Accelerate Auto

City of Greater Sudbury
Economic Development Department

Darryl Croft
President, Electric Vehicle Network Inc.

Dave Aelick
Director of Member Services, Used Car Dealers Association of Ontario (UCDA)

David Adams
President & CEO, Global Automakers of Canada

Drew Fagan
Professor, University of Toronto

Edward Fagan
Associate Partner, Zero Nexus

Emily Chung
Owner & 310S Journeyperson, AutoNiche Inc.

Frank Notte
Director of Government Relations, Motor Vehicle Retailers of Ontario

James F. Hamilton
Executive Director, Used Car Dealers Association of Ontario (UCDA)

James Ricci
President, Roy Foss Automotive Group

Ken Delaney
Executive Director, CSTEC

Leroy Martin
Co-owner, Elunity

Mark Lemay
Owner, Auto Aide Technical Services

Martyn Johns
National Director, NAPA Canada / UAP Inc.

Mike Bilton
Vice President, Supplier Programs, Automotive Parts Manufacturer's Association (APMA)

Nino Di Cara
Founder & President, Electric Autonomy Canada

R. Graeme Aitken
Executive Director, Electrical Contractors Association of Ontario

Sean De Vries
Executive Director, Battery Metals Association of Canada

Shannon M. Miller
Project Lead, Workforce & Talent Strategy, Ontario Vehicle Innovation Network

Stephen Bieda
Director, EV Society

Steve Fletcher
Managing Director, Automotive Recyclers of Canada

EXECUTIVE SUMMARY

The rapid development of Ontario's electric vehicle (EV) industry presents a generational economic opportunity for the province and its workforce. High-profile public and private investments in EV battery manufacturing, parts manufacturing, and automotive assembly, measured in the tens of billions of dollars, promise to create thousands of jobs directly and indirectly. These high-profile and highly scrutinized EV manufacturing infrastructure projects have rightfully attracted significant attention, but they are not the only part of Ontario's EV ecosystem that is worth talking about.

There are significant economic and employment opportunities related to EVs across the province. Upstream, critical minerals mining and processing, which provide essential materials for EV batteries and electronic systems, are a major opportunity for the mining industry in the regions of Northern Ontario—with employment implications for skilled workers such as miners, geologists, and mining engineers. The heart of Ontario's EV value chain is centred on midstream EV battery plants and automotive manufacturing facilities in Southern Ontario and the Greater Toronto Area, with roles for EV battery and automotive assemblers, as well as manufacturing and mechanical engineers, production technicians, and chemists, to name just a few.

Downstream, these finished EVs will need to be marketed and sold to consumers and provided with service and maintenance, with talent and skills implications for automotive marketers and salespeople, as well as automotive service technicians. EVs require regular access to electrical charging, and building a comprehensive network of charging infrastructure will be a significant task that will provide years of work for electricians and electrical contractors throughout Ontario. Moving into the post-stream, at the end of the EV's lifecycle, these vehicles, their batteries, and electronic components will need to be recycled with the valuable materials placed back into the EV supply chain, creating the opportunity for a circular EV economy in Ontario. The province's robust technology sector and digital economy workers, like software developers and data scientists, will support all segments of the EV value chain with automotive software applications, data services, and other needed digital technologies.

In fact, Ontario is one of the few jurisdictions in the world that has the potential to engage in the entire EV value chain: upstream, midstream, downstream, and post-stream. This makes Ontario's EV ecosystem unique in North America and underscores the importance of the EV industry to the province's economic and technological future, all with significant implications for the province's workforce and the talent development that will be needed to support Ontario's EV ecosystem.

This study characterizes Ontario's EV ecosystem and then maps the province's EV value chain segments to key supporting industries. It then provides an assessment of labour market and talent implications, including potential skill gaps and barriers for each segment of the EV value chain. While most jobs in Ontario's rapidly developing EV industry represent preexisting occupations, in many instances, those who wish to become involved in it will need to develop new skills and competencies directly related to EVs—for example, automotive service technicians will need to develop specific competencies through training to service and maintain EVs.

The study highlights the immense opportunity Ontario workers have to participate in the rapidly developing EV industry. Indeed, if Ontario can align all segments of its EV value chain along with the necessary workforce inputs and adequately train needed talent, the province has the potential to be a North American EV powerhouse.

CONTENTS

LIST OF ACRONYMS

AI	Artificial intelligence
AAM	Anode active material
BEV	Battery electric vehicle
CUSMA	Canada-United States-Mexico Agreement
DFM	Design for manufacturing
EDI	Equity, diversity, and inclusion
ESA	Electrical Safety Authority
EV	Electric vehicle
EVITP	Electric Vehicle Infrastructure Training Program
FOCAL	Future of Canadian Automotive Workforce Initiative
GDP	Gross domestic product
GTA	Greater Toronto Area
IEA	International Energy Agency
ICE	Internal combustion engine
ICE-V	Internal combustion engine vehicles
IIoT	Industrial internet of things
IoT	Internet of things
iZEV	Incentives for Zero-Emission Vehicles Program
NAFTA	North American Free Trade Agreement
NAPA	National Automotive Parts Association
NPI	New product introduction
PHEV	Plug-in hybrid electric vehicle
PPE	Personal protective equipment
STEM	Science, technology, engineering, and mathematics
OEM	Original equipment manufacturer
OMVIC	Ontario Motor Vehicle Industry Council
ON	Ontario
OVIN	Ontario Vehicle Innovation Network
PEG	Platinum group elements
QC	Quebec
R&D	Research and development
US	United States
USD	United States Dollar
WIL	Work-integrated learning
ZEV	Zero-emission vehicle(s)

INTRODUCTION

The rapid emergence of the electric vehicle (EV) industry in Ontario presents the province with a generational economic opportunity.[1] While the EV battery and automotive manufacturing facilities currently under construction are based in Southern Ontario and the Greater Toronto Area (GTA), there is a significant opportunity for most regions in Ontario to participate in the wider EV ecosystem, which includes mining and critical minerals processing, as well as charging infrastructure installation and management, EV sales and marketing, service and maintenance, and then battery and automotive recycling.

This study assesses the workforce and human capital implications of Ontario's emerging EV industry and its effect on skills and talent requirements throughout the upstream, midstream, downstream, and post-stream segments of the province's EV value chain. This value chain includes critical mineral mining and processing (upstream); EV battery assembly, automotive parts manufacturing, and vehicle assembly (midstream); EV sales and marketing, as well as service and maintenance (downstream); the installation and provision of EV charging infrastructure (downstream); and EV battery and vehicle recycling (post-stream).

1 A 2022 study by the Trillium Network for Advanced Manufacturing explores economic development scenarios for Canada's EV battery supply chain. Under the most bullish of these scenarios, which necessitates "enhanced contribution" to critical minerals mining and battery supply chain infrastructure, there could be a Canadian EV battery industry with a total economic output valued at $103 billion, supporting a workforce of over 322,000 workers, see: Trillium Network for Advanced Manufacturing, "Developing Canada's Electric Vehicle Battery Supply Chain: Quantifying the Economic Impacts and Opportunities," September 2022, https://trilliummfg.ca/wp-content/uploads/2022/09/Report_SupplyChainReport_v3_20220705_Publish_TNAM.pdf, 37.

Given that all of these value chain segments are supported by digital economy companies and workers that develop needed automotive software applications and data services, the study also covers the state of digital economy employment in Ontario's EV industry.[2] This study is focused on the EV industry in Ontario, and as such, it will not discuss other developments in the EV industry in other regions of Canada, such as electrification in Quebec's heavy and commercial vehicle sector.[3]

Ontario has the potential to participate in the totality of the EV value chain. Ontario is one of the few jurisdictions in the world with such potential. Preliminary analysis suggests there are significant employment opportunities in the EV industry throughout the province.[4] While few EV-specific jobs exist at the moment in Ontario, this can be expected to change in short order. The key manufacturing facilities that will support Ontario's EV industry, while in a nascent state at present, are currently under development and will come online within the next few years. The two best known to the public are the Volkswagen battery assembly plant under construction in St. Thomas, ON, and Stellantis and LG Energy Solution's NextStar Energy battery assembly plant under construction in Windsor, ON.

Furthermore, Ontario's pre-existing mining and automotive manufacturing sectors provide the province with precursor industries that can be leveraged toward building out the EV supply chain and key EV facilities in the province. The battery plants currently under development will require raw inputs of critical minerals such as lithium. Indeed, the mining and processing of critical minerals is another component of the EV value chain in which Ontario can participate. Though with long lead times to open new mines in the province, this is the most uncertain component of Ontario's EV ecosystem.

Ontario's large domestic market for vehicles and geographic proximity to the United States provides the province's EV industry with ready markets for critical minerals, battery and vehicle components, and finished vehicles. There will likely be notable disruptions to the automotive service and maintenance industry and automotive sales industry as more consumers adopt EVs. While present occupations in automotive service and vehicle sales are likely to continue existing, EVs will necessitate developing new skills for workers in these industries.

2 See: Alexandra Cutean, "Autonomous Vehicles and the Future of Work in Canada," Information and Communications Technology Council, 2017, https://ictc-ctic.ca/reports/autonomous-vehicles

3 See: Alexandra Cutean, et al., "Recharging Quebec's Transportation Sector," Information Communications Technology Council, January 2022, https://ictc-ctic.ca/reports/recharging-quebecs-transportation-sector

4 For example, see: FOCAL Initiative, "The Shift to EV Production in Canada's Automotive Manufacturing Sector: Assessing the Economic and Labour Market Impacts," February 2024, https://www.futureautolabourforce.ca/wp-content/uploads/2024/02/FOCAL-Initiative-The-Shift-to-EV-Production-in-Canadas-Automotive-Manufacturing-Sector-Assessing-The-Economic-And-Labour-Market-Impacts-compressed.pdf; Cedric Smith, et al., Taking Charge: How Ontario can create jobs and benefits in the electric vehicle economy, The Pembina Institute, 2021, https://www.pembina.org/reports/taking-charge.pdf

Building out needed EV charging infrastructure throughout Ontario presents both a significant challenge and a major employment opportunity. A failure to build out EV charging infrastructure to an appropriate level could dampen EV adoption and ultimately curtail the growth of the EV industry in Ontario. Likewise, the automotive, battery, and electronics recycling industries in Ontario will need to adapt to the mass adoption of EVs in Canada. Like other workforces tied to the EV value chain, automotive recyclers will need to upskill their workforces and develop new processes to safely and economically recycle EVs that have reached the end of their useful lives.

Throughout the entire value chain, there are significant opportunities for digital economy workers, who will need to develop and maintain the software to support this myriad of EV industries in Ontario.

This study does not cover ancillary but important issues related to Ontario's emerging EV ecosystem, such as the implications for the province's electricity supply and electrical grid infrastructure,[5] training and upskilling for first responders,[6] and the potential for increased wear on road infrastructure from heavier EVs such as buses and heavy trucks, thus increasing road maintenance.[7] Construction-related employment created by the significant build-out of battery manufacturing facilities or the retooling of automotive parts manufacturing and vehicle assembly facilities in Ontario is also not directly covered. Likewise, the study does not cover other types of low- or zero-emission vehicles, such as hydrogen fuel-cell vehicles and hybrid vehicles.[8,9]

5 See: David Campbell, et al., "Project of the Century: A Blueprint for Growing Canada's Clean Electricity Supply – and Fast," Public Policy Forum, July 19, 2023, https://ppforum.ca/publications/net-zero-electricity-canada-capacity/

6 See: Nour Elsagan & M. Hamed Mozaffari, "Literature Review on Parking of Electric Vehicles," National Research Council of Canada, Report no. A1-02202.1, June 1, 2023, https://publications.gc.ca/collections/collection_2023/cnrc-nrc/NR24-120-2023-eng.pdf, 18-19.

7 See: John M. Low, et al., "The hidden cost of road maintenance due to the increased weight of battery and hydrogen trucks and buses—a perspective," Clean Technologies and Environmental Policy, vol. 25, 2023, https://doi.org/10.1007/s10098-022-02433-8

8 "Hydrogen Fuel-Cell Vehicles: Everything You Need to Know," Car and Driver, September 26, 2022, https://www.caranddriver.com/features/a41103863/hydrogen-cars-fcev/

9 "What Is a Hybrid Car and How Do They Work?" Car and Driver, February 5, 2024, https://www.caranddriver.com/features/a26390899/what-is-hybrid-car/

WHAT IS AN ELECTRIC VEHICLE?

An electric vehicle (EV) uses electricity supplied by a powerful, high-capacity battery to power its powertrain and other subsystems.[10] Unlike conventional vehicles, which are powered by an internal combustion engine (ICE), EVs do not use fossil fuels such as gasoline, diesel, or propane.[11] Rather than filling a tank with fuel, a driver recharges an EV from an electrical outlet or a specialized charging station. Common components for all EVs include an electric motor, battery pack, power inverter, regenerative braking system, thermal cooling system, charging port, and a digital control system and driver interface.[12] Most EVs also include single-speed transmissions.[13]

For this report's purposes, EVs refer to passenger vehicles, such as cars, sport utility vehicles, and pickup trucks, as well as light commercial vehicles, such as delivery vans. Smaller electric transportation solutions, such as e-bikes and electric scooters, are beyond the scope of this research. Similarly, electric alternatives to vehicles used in freight shipping, whether by road, train, ship, or air, are also out of scope.

10 McKinsey & Company, "What is an EV?" February 6, 2023, https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-an-ev.

11 Though, the composition a region's electricity generation will affect how carbon-intensive charging and operating an EV will be. In Ontario, over 70% of Ontario's electrical generation capacity is made up of nuclear, hydroelectric, and renewable energy sources, see: Independent Electricity System Operator (Ontario), "Ontario's Electricity Grid: Transmission-Connected Capacity," accessed March 20, 2024, https://www.ieso.ca/en/Learn/Ontario-Electricity-Grid/Supply-Mix-and-Generation.

12 See: Chris Bouchard, "The Key Components of an Electric Vehicle," DataOne, May 2023, https://vin.dataonesoftware.com/vin_basics_blog/electric-vehicle-key-components

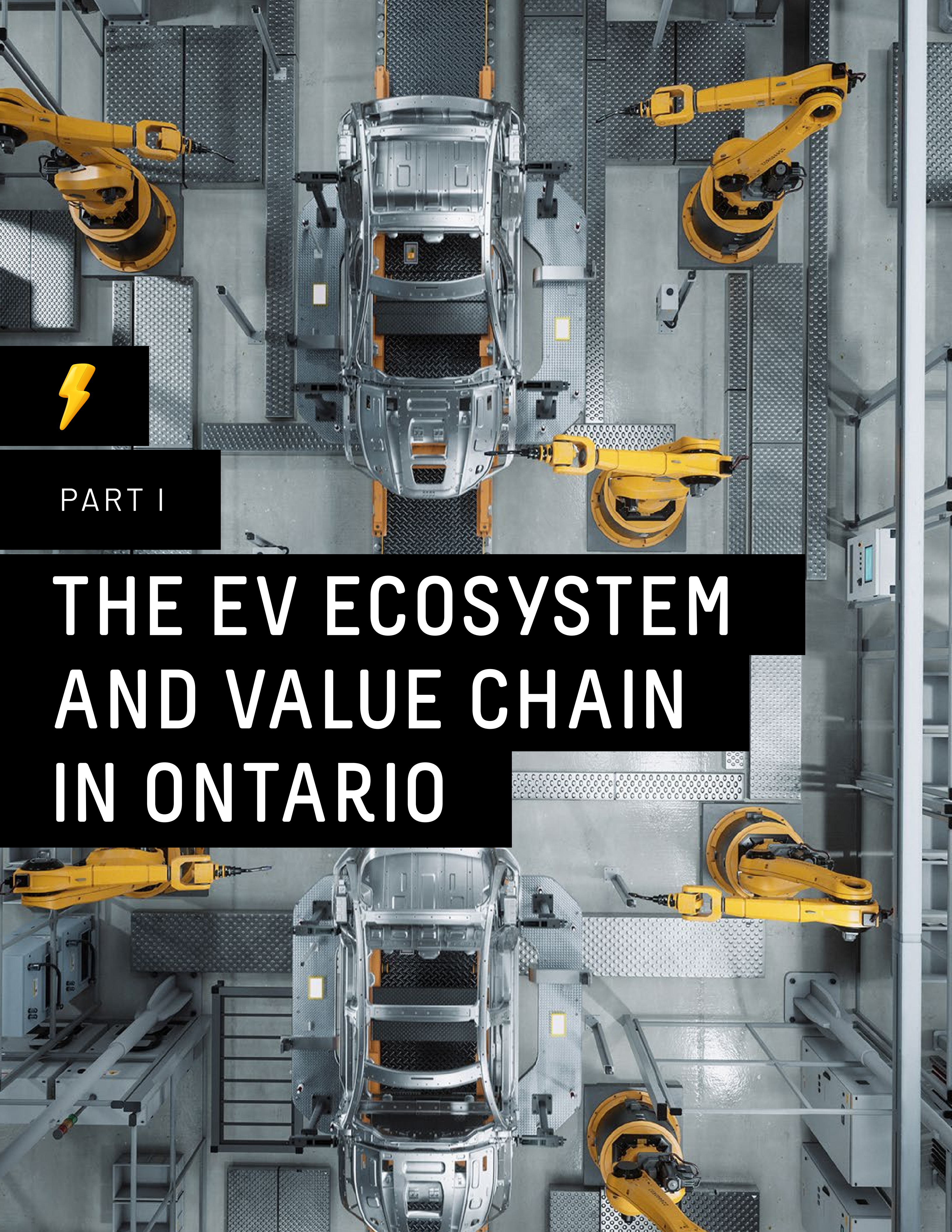
13 "Do Electric Cars Have Transmissions?" Mazda, August 2, 2023, https://www.mazdausa.com/resource-center/do-electric-cars-have-transmissions.

STUDY OVERVIEW

The study uses a value chain approach to map Ontario's EV industry and better understand the labour force and talent demand for the various nodes that make up the province's EV ecosystem. It maps these nodes to specific occupations, as derived from ICTC's primary data collection and secondary literature. It also includes an environmental scan and review of key contemporary issues and trends affecting Ontario's emerging EV industry.

This report begins by defining Ontario's EV value chain and discussing its key segments. It then provides an overview of the present state of EV industry development in the province, including critical policy supports and key public and private investments in EV battery and automotive manufacturing facilities. Following this, it provides a detailed discussion of workforce demand and supply, as well as workforce development barriers in the EV value chain's upstream (critical minerals mining and processing), midstream (battery, automotive parts, and vehicle manufacturing), downstream (vehicle sales and marketing, service and maintenance, and charging infrastructure), and finally post-stream (battery and automotive recycling) phases. It will also provide an analysis of digital economy jobs that support the Ontario EV ecosystem.

ICTC's research into Ontario's EV workforce is based on information and insights provided by 34 in-depth interviews with employers and experts from Ontario's EV industry, an employer survey of 155 EV employers throughout Canada, web scraping of EV-related job postings in Canada and the United States, and the comments and feedback provided by a ten-member advisory committee of Ontario-based EV leaders. These primary data collection methods were complimented and corroborated through an extensive literature review and environmental scan of the EV ecosystem in Ontario, as well as through the examination and analysis of publicly available third-party and government data. A detailed explanation of research methods applied to this study, as well as known research limitations, is available in Appendix I of this report.



PART I

THE EV ECOSYSTEM AND VALUE CHAIN IN ONTARIO

ONTARIO'S EV VALUE CHAIN

A value chain refers to the step-by-step process undertaken by a firm to produce a value-added product or service. Academic Michael Porter uses the concept of the "value chain" to break an organization down into its various sub-components to understand the primary activities and supporting processes that take inputs and turn them into a valuable product or service.[14] It includes both the supply chain, with its material and logistical considerations, and the value-added processes that firms undertake to create goods or services. A value chain can be broadened conceptually to cover an entire industry or sector of the economy.

For example, for this study's purposes, the concept of the value chain is applied to the entirety of Ontario's EV industry. This allows for seemingly unrelated industries—such as critical minerals mining and automotive sales—to be linked together in a logical model and thus provide a bigger picture of the EV ecosystem in Ontario and its total workforce and talent implications.

Ontario's emerging EV industry has an extensive value chain encompassing upstream, midstream, downstream, and post-stream segments. It starts downstream with critical minerals mining and processing and then moves to the midstream manufacturing of EV battery materials and components manufacturing, battery pack assembly, EV parts manufacturing, and final automotive assembly. Throughout the value chain, digital economy firms will also provide products such as vehicle software and data systems to digitally enable these vehicles.

14 "The Value Chain," Institute for Strategy & Strategic Competitiveness, Harvard Business School, accessed February 13, 2024, https://www.isc.hbs.edu/strategy/business-strategy/Pages/the-value-chain.aspx

Table 1: Upstream, Midstream, Downstream, and Post-Stream Segments of Ontario's EV Value Chain

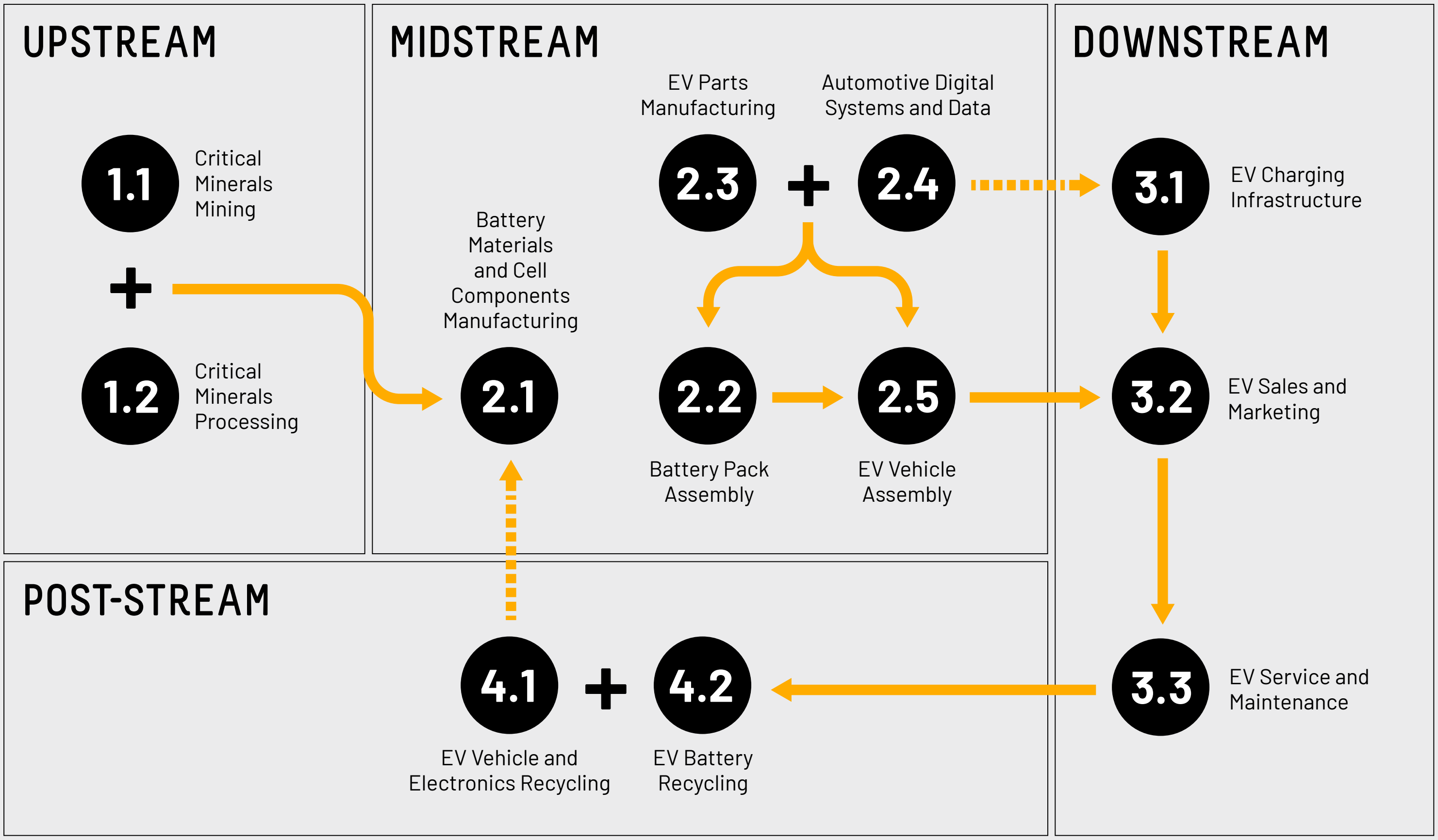
VALUE CHAIN SEGMENT	INDUSTRIES INCLUDED	DIGITAL ECONOMY EXAMPLES
Upstream	Critical minerals exploration and mining Critical minerals processing	AI-enabled exploration applications IIoT mine operations ("smart mines")
Midstream	EV battery materials and components manufacturing EV battery assembly EV parts/vehicle manufacturing Automotive digital systems and data	Battery cell/pack QA/QC (data science) Battery management software Parts inventory/analytics Automotive cybersecurity
Downstream	EV charging infrastructure EV sales and marketing EV service and maintenance	Public EV charger remote payments Digital auto sales platforms EV performance telemetry data
Post-stream	EV battery recycling EV/electronics recycling	Parts inventory/predictive analytics Used EV battery digital marketplaces

Source: ICTC Ontario EV workforce study primary and secondary research synthesis, ICTC 2024.

Mapping Ontario's EV Value Chain

This EV value chain—which closely aligns with the lifecycle of an individual EV—is mapped out and presented in Figure 1. The segments (numbered 1.1 to 4.2) represent the various major segments in the EV value chain, with arrows pointing to the direction of the flow of raw materials, manufactured components, and the finished vehicles take through an EV's lifecycle.

Figure 1: Ontario's EV Value Chain



Source: ICTC Ontario EV workforce study primary and secondary research synthesis, ICTC 2024.

Description: Segments 1.1 and 1.2 represent upstream critical minerals mining and processing. Segments 2.1 and 2.2 represent midstream battery materials and components manufacturing, segments 2.3 and 2.4 automotive parts manufacturing and the development of automotive digital systems and data services, and 2.5 final vehicle assembly. Downstream, segment 3.1 represents installing and maintaining public and private EV charging infrastructure, segment 3.2 represents EV sales and marketing (both new and used vehicles), and segment 3.3 EV service and maintenance. Moving on to post-stream, segment 4.1 represents vehicle and electronics recycling, while segment 4.2 represents EV battery recycling. The value chain map ends with a dotted arrow linking 4.2 and 2.1, highlighting a potential circular economy between the battery recycling industry and the EV battery materials and components manufacturing industry.

The resulting value chain map should be thought of as a model of reality rather than a perfect one-to-one representation of reality. By necessity, the value chain presented in Figure 1 coarsely combines thousands of individual steps throughout critical minerals mining, automotive manufacturing, and downstream sales, service, charging, and post-stream recycling processes. It is intended to simplify and illustrate the process of automotive manufacturing and its related upstream, downstream, and post-stream activities in a way that can meaningfully discuss the workforce and talent implications of Ontario's EV value chain while not indulging in overwhelming detail.

Furthermore, Figure 1 does not include second-order inputs into the value chain, such as the construction of EV battery manufacturing infrastructure or the increase in electricity generation needed to power EV charging infrastructure. As noted in the introduction of this paper, while such ancillary factors are an important consideration for Ontario's EV industry, they are beyond the scope of this research.

A POLICY SCAN OF ONTARIO'S EV ECOSYSTEM

The ongoing emergence of Ontario's EV industry is not a spontaneous development but a product of federal and provincial public policy. This section discusses key federal and provincial policies that have served to develop an EV manufacturing industry in Ontario in a short amount of time.

Ontario Provincial Strategy

The Ontario government is seeking to attract significant investment in EV manufacturing capacity as it tries to electrify its transportation system, curtail carbon emissions, and maintain its large automotive manufacturing industry in Southern Ontario. Recognizing the importance of automotive manufacturing in Ontario, the provincial government produced a series of strategies and policies to maintain the province's automotive industry in the face of an acute, multi-year decline in vehicle production and automotive manufacturing jobs.

Between 2019 and 2021, the Ontario government released a two-part automotive manufacturing strategy to maintain and deepen the province's strengths in automotive manufacturing in North America. The strategy seeks to link the province's historical prowess in automobile manufacturing with its status as a major North American technology and innovation hub.[15] It seeks to maintain a competitive business climate while developing talent and innovative technological advancements in the automotive industry. It calls for the repositioning of Ontario's automotive assembly and vehicle parts industries to produce the "car of the future," including autonomous vehicles and EVs.[16]

Recognizing the potential of Ontario's mining sector for the EV industry's critical minerals supply, the strategy also calls for the province to establish itself as a hub for EV battery production by anchoring up to three battery plants in the province.[17] By adopting this strategy, Ontario has the potential to establish a robust domestic EV manufacturing supply chain. Indeed, an analysis by KPMG suggests that Ontario has distinct advantages in the manufacture of EVs due to its domestic access to critical minerals and its legacy automotive manufacturing industry.[18]

Ontario's automotive strategy also recognizes the importance of workforce development, with the strategy promoting STEM learning for Ontario primary and secondary school students, investing in worker training through programs such as targeted micro-credentials, supports for secondary school students to pursue skilled trades, apprenticeships, and specialized post-secondary education programs.[19] The policy direction laid out in the automotive manufacturing strategy was buttressed by Ontario's 2020 *A Made-in-Ontario Environment Plan*, which seeks to cement the province's reputation as an environmentally responsible jurisdiction to do business.[20]

15 Government of Ontario, "Driving Prosperity: The Future of Ontario's Automotive Sector," last update: September 20, 2022, https://www.ontario.ca/page/driving-prosperity-future-ontarios-automotive-sector

16 Government of Ontario, "Driving Prosperity: Ontario's Automotive Plan Phase 2," 10-12.

17 Ibid., 13-14.

18 KPMG, "Mine the gap: Canada's opportunity to lead the race to an EV future," October 27, 2022, https://kpmg.com/ca/en/home/insights/2022/10/mine-the-gap.html; KPMG, "How Canada could become a global powerhouse in EV production," June 20, 2022, https://kpmg.com/ca/en/home/insights/2022/06/how-canada-could-become-a-global-powerhouse-in-ev-production.html#

19 Government of Ontario, "Driving Prosperity: Ontario's Automotive Plan Phase 2," 17-18.

20 Government of Ontario, "A Made-in-Ontario Environment Plan," last update: September 20, 2022, https://www.ontario.ca/page/made-in-ontario-environment-plan

Ontario's 2022 critical minerals strategy places a heavy emphasis on developing and stewarding the province's critical minerals resources toward EV battery production and supply chains.[21] Critical mineral exploration incentives such as flow-through shares and grant funding to enhance junior exploration efforts—such as the Ontario Junior Exploration Program—are key elements to developing critical mineral mines in the province.[22] The critical minerals strategy aims to enhance geoscience information platforms and exploration efforts while better connecting the supply chain of the mines in Northern Ontario with the manufacturing sector in Southern Ontario.[23] The critical minerals strategy notes how Ontario's mining sector supported more than 28,000 direct jobs in 2022, and by 2025, the industry will need to hire between 30,000 and 48,000 new employees to fill its projected labour demand.[24]

Federal Government Strategy

Like the Province of Ontario, the federal government has taken strategic measures to increase the manufacture and use of EVs in Canada. Coinciding with the release of Ontario's critical minerals strategy, the federal government released its own national critical minerals strategy in 2022.[25] The strategy notes that "critical minerals are the building blocks for the green and digital economy" and highlights those key critical minerals essential in the EV battery supply chain, such as cobalt, graphite, lithium, and nickel, are in "abundance" in Canada.[26] It also calls for the responsible exploration and development of critical minerals projects in Canada and highlights the potential for a circular economy to be developed between Canada's critical minerals processing and the battery and electronics recycling industry.[27]

In December 2023, the federal government announced its Electric Vehicle Availability Standard, which mandates that all new light-duty vehicles sold in Canada must be zero-emission vehicles (ZEVs) by 2035.[28] The regulation calls for 20% of new vehicles sold in Canada to be ZEVs by 2026, ramping up annually to 100% by 2035; see Table 2.

Table 2: Government of Canada Electric Vehicle Availability Standard, ZEV Sales Targets (2026-2035)

	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035+
ZEV Target	20%	23%	34%	43%	60%	74%	83%	94%	97%	100%

Data source: Environment and Climate Change Canada (Government of Canada), "Canada's Electric Vehicle Availability Standard (regulated targets for zero-emission vehicles)," 2023.

21 Government of Ontario, "Ontario's Critical Minerals Strategy 2022–2027: Unlocking potential to drive economic recovery and prosperity," March 2022, https://www.ontario.ca/files/2022-03/ndmnrf-ontario-critical-minerals-strategy-2022-2027-en-2022-03-22.pdf

22 Ibid., 47-53.

23 Ibid.

24 Ibid., 40-41.

25 Government of Canada, "The Canadian Critical Minerals Strategy: Powering the Green and Digital Economy for Canada and the World," 2022, https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html

26 Ibid.

27 Ibid.

28 Environment and Climate Change Canada (Government of Canada), "Canada's Electric Vehicle Availability Standard (regulated targets for zero-emission vehicles)," last update: December 19, 2023, https://www.canada.ca/en/environment-climate-change/news/2023/12/canadas-electric-vehicle-availability-standard-regulated-targets-for-zero-emission-vehicles.html

Under its Incentives for Zero-Emission Vehicles Program (iZEV), the federal government offers a point-of-sale incentive program that covers up to $5,000 on the cost of purchasing or leasing an approved ZEV, including battery electric vehicles (BEVs).[29] The program only covers new vehicles at present, though this incentive may be applied to used BEVs in the future.[30] Significant changes to the iZEV program are expected to be announced in the 2024 federal budget. The Government of Ontario does not currently offer a similar financial incentive program for EV purchases.[31]

Public Investment in Key Ontario EV Battery Facilities

The federal government and the provincial governments of Ontario and Quebec have recently invested significantly in three EV battery manufacturing facilities, along with smaller supporting investments in battery materials facilities. A December 2023 report by the Parliamentary Budget Officer estimates that total federal and provincial funding for three EV battery facilities in Ontario and Quebec totals $43.6 billion, including production and tax subsidies and support for construction costs.[32] This includes $2.2 billion in construction support and $28.2 billion in production subsidies in Ontario alone. Furthermore, the federal and Ontario governments will provide a combined $975.9 million in public investments for the Umicore battery materials plant in Loyalist Township, ON, and the federal and Quebec governments will provide a combined total of $644 million for the Ford battery materials plant in Bécancour, QC.[33] See Table 3 below.

Table 3: Public Investment in Key Ontario and Quebec EV Battery Facilities

EV BATTERY FACILITY	LOCATION	TOTAL PUBLIC INVESTMENT ($CAD)
Stellantis-LG Energy Solution, NextStar Energy battery plant	Windsor, ON	$16 billion
Volkswagen battery plant	St. Thomas, ON	$14.4 billion
Northvolt battery plant	Montreal region, QC	$7.3 billion
Umicore battery materials plant	Loyalist Township, ON	$975.9 million
Ford EV battery materials plant	Bécancour, QC	$644 million

Data source: Office of the Parliamentary Budget Officer (Government of Canada), "Costing Support for EV Battery Manufacturing," November 2023.

29 Royal Bank of Canada (RBC), "Your Guide to Canada's Electric Car Rebates: Incentives for Zero-Emission Vehicles Program (iZEV)," accessed March 10, 2024, https://www.rbcroyalbank.com/sustainable-finance-solutions/electric-car-guide/electric-car-rebates.html.

30 "Ottawa looking at including used cars in federal electric vehicle incentive, report says, " CBC News, December 24, 2023, https://www.cbc.ca/news/politics/guilbeault-used-electric-vehicle-federal-incentive-1.7068275.

31 Royal Bank of Canada (RBC), "Your Guide to Canada's Electric Car Rebates: Incentives for Zero-Emission Vehicles Program (iZEV): Ontario: Are EV rebates available in my province?"

32 Office of the Parliamentary Budget Officer (Government of Canada), "Costing Support for EV Battery Manufacturing," November 2023, https://www.pbo-dpb.ca/en/publications/RP-2324-020-S—costing-support-ev-battery-manufacturing—etablissement-couts-soutien-accorde-fabrication-batteries-ve

33 Ibid.

According to experts interviewed as part of this research, these significant public investments in EV battery manufacturing infrastructure are an attempt to corner a portion of the global EV supply chain in Ontario and Quebec while allowing industries upstream and downstream of battery manufacturing to colocate near these battery plants to form production supply chains. In this way, the production of EV batteries forms the nexus for Ontario's entire EV ecosystem.

Public investment in Ontario and Quebec has been particularly rich due to competition from the United States (US)—a neighbouring country with significantly deeper pockets—to attract battery plants. The Center for American Progress notes that US industrial policy, including the Inflation Reduction Act, has produced an "American manufacturing renaissance" of EV production, already spurring $92.3 billion (USD) in EV and battery manufacturing in the US.[34]

Key Investments in Other Aspects of Ontario EV Manufacturing

Alongside headline investments in Stellantis-LG Energy Solution's NextStar Energy battery plant, Volkswagen's St. Thomas battery plant, and Umicore's battery materials plant, automotive manufacturing companies and automotive parts manufacturing companies have also made significant investments into Ontario's EV ecosystem. Notable recent announcements from automotive manufacturers include Ford's $1.8 billion investment to upgrade its Oakville Assembly Plant to produce EVs[35] and Stellantis' announcement that it will produce EVs at its Windsor Assembly Plant.[36] While General Motors' CAMI Assembly plant in Ingersoll, ON, has had a production line for electric BrightDrop delivery vans since 2022,[37] General Motors will also be opening a new battery module facility in Ingersoll in 2024.[38] There is also potential for Tesla to invest in EV facilities in Ontario, as recent reports by Electric Autonomy Canada indicate.[39]

Automotive parts manufacturers are also investing heavily to produce components for EVs. For example, Magna International has invested in EV parts manufacturing facilities in Brampton and Guelph, ON,[40] and Linamar is constructing a "gigacasting" facility in Welland, ON.[41] In 2022, automotive parts manufacturer Flex-N-Gate opened its Flex-Ion Battery Innovation Centre in partnership with the Ontario government and the municipality of Windsor. The centre is currently developing novel EV technologies, such as "extreme-fast charging" EV batteries, in partnership with private companies and local higher education institutions.[42]

34 Leo Banks, "How Inflation Reduction Act Electric Vehicle Incentives Are Driving a U.S. Manufacturing Renaissance," Center for American Progress, November 2023, https://www.americanprogress.org/article/how-inflation-reduction-act-electric-vehicle-incentives-are-driving-a-u-s-manufacturing-renaissance/

35 "Ford Motor Co. unveils details of plan to spend $1.8B in Oakville to produce electric vehicles," CBC News, April 11, 2023, https://www.cbc.ca/news/canada/toronto/ford-motor-oakville-electric-vehicles-1.6806817

36 "New electric Dodge Charger will be built in Windsor, Ont., Stellantis says," CBC News, March 5, 2024, https://www.cbc.ca/news/canada/windsor/windsor-dodge-charger-stellantis-1.7134146

37 "A van from GM's brand-new Ontario electric vehicle plant could soon be bringing a package to your door," Toronto Star, December 5, 2022, https://www.thestar.com/news/canada/2022/12/05/a-van-from-gms-brand-new-ontario-electric-vehicle-plant-could-soon-be-bringing-a-package-to-your-door.html; Though the production of BrightDrop delivery vans are reported to be facing significant production delays due to challenges with its battery supply chain and have been paused until spring 2024, see: "General Motors' (GM) Ontario Plant Halts BrightDrop Production," Yahoo! Finance, September 20, 2023, https://finance.yahoo.com/news/general-motors-gm-ontario-plant-112800298.html

38 "General Motors confirms it will make Ultium battery packs at new plant in Ingersoll, Ont.," Electric Autonomy Canada, July 26, 2023, https://electricautonomy.ca/2023/07/26/general-motors-battery-modules-cami/

39 "Tesla, Ontario met about 'investment opportunities' for years, government records show," Electric Autonomy Canada, August 22, 2023, https://electricautonomy.ca/2023/08/22/tesla-ontario-investment-opportunities-exclusive/

40 "Magna investing $470 million to build new Ontario battery assembly plant, retool factories," Financial Post, February 15, 2023, https://financialpost.com/commodities/energy/electric-vehicles/magna-470million-new-ontario-battery-plant

41 "Linamar to supply EV industry from new Ontario gigacasting plant, " Electric Autonomy Canada, November 1, 2023, https://electricautonomy.ca/2023/11/01/linamar-gigacasting-ontario-evs/

42 "Windsor firm partners to build 'extreme-fast charging' e-vehicle batteries," Windsor Star, October 10, 2023, https://windsorstar.com/news/local-news/extreme-fast-charging-battery-firm-partners-with-windsors-flex-ion-battery-centre

PART II

⚡ UPSTREAM

CRITICAL MINERALS MINING AND PROCESSING

Overview of Critical Minerals Mining and Processing

Ontario's EV ecosystem requires critical minerals—such as cobalt, lithium, and nickel—as key inputs for EV batteries and EV electronic systems.[43] For Ontario's EV industry to be successful and globally competitive, securing significant and reliable sources of EV-critical minerals is paramount. Failure to secure these resources would serve to undermine the already significant EV investment taking place in Southern Ontario and minimize value-capture opportunities. Critical minerals will need to be sourced either domestically or from abroad and integrated into Ontario's EV supply chain. While the EV industry is exploring how to recycle and reuse critical minerals at scale, for the foreseeable future, the most common method to source these critical minerals will be to mine them. Yet, as the World Economic Forum observes, mining critical minerals comes with a high degree of environmental and social risks.[44] Responsible and sustainable stewardship of critical mineral resources is vital.

Critical minerals represent relatively scarce but essential inputs into advanced technologies in aerospace and defence, telecommunications, computer hardware, and clean energy applications.[45] According to the International Energy Agency (IEA), demand for critical minerals is expected to greatly increase as the world transitions to clean energy.[46] The scarcity of critical minerals may be driven by their overall rareness, but it can also be driven by scarcity within a specific supply chain. A mineral that may be in abundant supply in one region of the world may be difficult to source but greatly needed in another.

For Ontario's rapidly developing EV industry, significant amounts of critical mineral inputs are required to build EV batteries. The IEA estimates that an EV requires six times the critical mineral inputs to construct compared to a conventional ICE vehicle.[47] This includes materials for the EV battery as well as the vehicle's electronic systems. The main minerals needed in the development of EV batteries are lithium, nickel, cobalt, manganese, and graphite.[48] Each of these minerals is important to battery performance.[49]

Despite the significance of all critical minerals in the process, the supply of lithium and cobalt is often the focus. Lithium's importance comes from its role in moving between the graphite in the anode and the cobalt in the cathode, which ultimately produces electricity. It is worth noting that the reduction of cobalt content in the cathode and a shift to nickel-rich cathodes are anticipated in the near term for passenger EVs.[50] In short, critical minerals are integral to the EV battery lifecycle.

43 Critical Minerals Centre of Excellence, "Critical minerals: an opportunity for Canada," Government of Canada, last updated August 18, 2022, https://www.canada.ca/en/campaign/critical-minerals-in-canada/critical-minerals-an-opportunity-for-canada.html

44 "Critical minerals enable the energy transition. We must learn to use them sustainably," World Economic Forum, January 15, 2024, https://www.weforum.org/agenda/2024/01/energy-transition-critical-minerals-technology/

45 Mining Association of Canada, "Critical Minerals," accessed May 10, 2023, https://mining.ca/our-focus/critical-minerals/

46 International Energy Agency, "Critical minerals: The role of critical minerals in clean energy transitions," accessed May 10, 2023, https://www.iea.org/topics/critical-minerals

47 International Energy Agency, "The Role of Critical Minerals in Clean Energy Transitions," May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

48 Invest in Canada, "EV Supply Chain," https://www.investcanada.ca/industries/ev-supply-chain; Federal Consortium for Advanced Batteries, "National Blueprint For Lithium Batteries," United States Department of Energy, January 2021, https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf

49 Ibid., 5.

50 International Energy Agency, "The Role of Critical Minerals in Clean Energy Transition," Revised version, March 2022, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions, 96-97

As the transition to EVs accelerates over the next decade, spurred on by federal EV sales mandates, a secure supply of battery materials will be vital to support the competitiveness of Ontario's EV industry. Significant critical minerals mining, as well as battery materials recycling, will be a long-term endeavour. Demand for critical minerals is projected to grow as drivers around the world adopt EVs. Indeed, the IEA projects that between the present day and the year 2040, demand for elements such as cobalt will increase by 21 times its current level, while nickel will increase by 41 times and lithium by 43 times.[51] This represents a truly significant increase in global demand for key EV-critical minerals; see Table 4 below.

Table 4: Global Demand Growth for Critical Minerals between 2020 and 2040

CRITICAL MINERALS	DEMAND GROWTH
Lithium	**43x** Current Levels
Nickel	**41x** Current Levels
Copper	**28x** Current Levels
Graphite	**25x** Current Levels
Cobalt	**21x** Current Levels

Data source: IEA, "The Role of Critical Minerals in Clean Energy Transition, 2022."

Furthermore, as some experts interviewed for this study cautioned, demand for critical minerals, such as nickel, by the aerospace and defence sector may increase concurrently with demand from the EV industry as countries such as the United States seek to recapitalize their armed forces. This could create a situation where EV manufacturing will be in direct competition with defence procurement for scarce critical minerals inputs. Currently, critical mineral processing is globally concentrated, with China accounting for nearly 60% of critical mineral processing, while Central America and South America account for 40%, according to a recent report by the Center for Strategic and International Studies.

Critical Minerals in Ontario

Critical mineral ores, such as lithium and graphite, require the processing of the raw mined material to create a usable product, presenting an opportunity for Northwestern Ontario in chemical processing and conversion of critical mineral materials into processed inputs.[54] Northwestern Ontario is an emerging lithium exploration market, with some sites in the province anticipating production by early 2026.[55]

51 Ibid.

52 Also, see: Fabian Villalobos & Morgan Bazilian, "Militaries, Metals, and Mining," RAND, April 18, 2023, https://www.rand.org/pubs/commentary/2023/04/militaries-metals-and-mining.html.

53 Joseph Majkut, et al., "Building Larger and More Diverse Supply Chains for Energy Minerals," July 19, 2023, https://www.csis.org/analysis/building-larger-and-more-diverse-supply-chains-energy-minerals, 4-6.

54 Thunder Bay Community Economic Development Commission, "Mining Readiness Strategy: A guiding framework for the City of Thunder Bay to support the growing Northwestern Ontario mining sector," City of Thunder Bay, December 15, 2020, https://gotothunderbay.ca/wp-content/uploads/2021/02/CEDC-MiningReadinessStrategy-2021.pdf, 14.

55 "Mining the Northwest: How Northern Ontario's first lithium mine and refinery project could come together," Northern Ontario Business, July 6, 2023, https://www.northernontariobusiness.com/mining-the-northwest/mining-the-northwest-how-northern-ontarios-first-lithium-mine-and-refinery-project-could-come-together.html

Further developments are underway to establish Canada's first lithium processing refinery site with an operational date of 2028 while also building out supply chain opportunities through a lithium battery recycling facility and a patent-focused research and innovation centre.[56]

Frontier Lithium and Mitsubishi have announced a joint venture that will establish the first fully integrated lithium mining and processing operation in the region.[57] Given that building out Ontario's EV value chain will require so many of these "firsts," innovation-focused initiatives and international partnerships will be key to leveraging technologies and securing adequate financing that enables further processing opportunities. Table 5 highlights the primary critical mineral opportunities in Ontario.

Table 5: Ontario Production and Exploration Status of Key Critical Minerals

CRITICAL MINERAL	DETAILS
Chromite	"The Ring of Fire, in the Far North of Ontario, has the second largest chromite deposit globally in terms of ore resources."
Cobalt	"In 2022, Ontario produced an estimated 1,235 tonnes of by-product cobalt worth approximately $96 million, making up 36% of Canada's cobalt production."
Copper	"Copper produced in Ontario in 2022 totalled 32% of Canada's copper production by value, with 160,030 tonnes valued at $1,926 million."
Graphite	"Ontario has several active graphite exploration programs."
Lithium	"Ontario has several hard-rock lithium deposits that are being actively explored in the hopes of eventually supplying raw materials for electric vehicle batteries."
Nickel	"In 2022, Ontario produced 71,277 tonnes of nickel valued at $1,883 million (45% of Canada's nickel production by value)."
Platinum Group Elements (PGE)[58]	"In 2022, Ontario produced 77% of Canada's PGE production by value with an estimated 547,232 troy ounces of PGE valued at $1,644 million."
Vanadium	"Ontario has exploration potential for vanadium exploration in southeastern Ontario."

Source: Natural Resources Canada and the Ministry of Mines, "Mineral Production: Ontario 2023," April 20, 2023, https://files.ontario.ca/mines-mineral-production-ontario-2023-en-2023-05-29.pdf

56 "Avalon announces bigger plans for lithium plant site," TBnewswatch.com, September 16, 2023, https://www.tbnewswatch.com/local-news/avalon-announces-bigger-plans-for-lithium-plant-site-7557646

57 "Frontier Lithium and Mitsubishi Corporation form joint venture to advance the first fully integrated lithium operation in Ontario, Canada," Cision Canada, March 4, 2024, https://www.newswire.ca/news-releases/frontier-lithium-and-mitsubishi-corporation-form-joint-venture-to-advance-the-first-fully-integrated-lithium-operation-in-ontario-canada-876351994.html

58 Platinum Group Elements (PEG), include platinum, palladium, rhodium, ruthenium, iridium, and osmium.

However, when compared to other parts of Ontario's EV ecosystem, critical minerals mining for EV applications is relatively underdeveloped. Mining for most critical minerals is, for the most part, still in the exploratory phase in the province. This is despite a long history of mining in Ontario and 344,825 active mining claims as of late 2022.[59] As Ontario looks to enhance its critical minerals exploration and extraction efforts, expanding processing capacity will be central to enhancing the value capture of critical minerals.

According to Natural Resources Canada data, as this report was published, there are a dozen active mining projects producing critical minerals in Ontario at present and seven operational critical minerals processing facilities in the province. There are also 24 critical minerals mining projects in advanced stages of development.[60] Figure 2 below visualizes active critical mineral mines, processing facilities, and exploration projects throughout Ontario.

Figure 2: Ontario Critical Minerals Project Map (as of March 2024)

Source: Natural Resources Canada and the Ministry of Mines, "Mineral Production: Ontario 2023," April 20, 2023, https://files.ontario.ca/mines-mineral-production-ontario-2023-en-2023-05-29.pdf

59 Natural Resources Canada (Government of Canada) & Ministry Mines (Government of Ontario), "Mineral Production: Ontario 2023," April 20, 2023, https://files.ontario.ca/mines-mineral-production-ontario-2023-en-2023-05-29.pdf

60 Natural Resources Canada (Government of Canada), "Canada's Critical Minerals Map," accessed May 1, 2023, https://atlas.gc.ca/critical-minerals/en/

Critical mineral development is concentrated in Northern Ontario. As such, communities in Northern Ontario are already benefiting from employment and entrepreneurial spin-off opportunities from critical mineral mining and exploration. Indeed, mining is a dominant industry in Northern Ontario, employing over a third of the workforce.[61] Yet, mineral and chemical processing facilities are concentrated in the southern regions of the province, with relatively fewer mineral processing facilities located in Northern Ontario.

However, large-scale mining and mineral processing projects are normally multi-decade affairs.[62] These projects are subject to multi-year regulatory approval processes. They require significant upfront capital investment, which may not enjoy returns for years, and are subject to significant risk. For these reasons, obtaining financing for critical minerals projects in Northern Ontario and elsewhere in Canada could prove to be challenging. Just because there are proven critical mineral reserves in places like Northern Ontario's "Ring of Fire," a 5,000 square kilometre region in Northern Ontario located 500 kilometres northeast of Thunder Bay, does not necessarily mean these resources will be developed.

Still, regions like the Ring of Fire hold significant promise for critical mineral mining in the province.[63] As interest in critical minerals mining increases due to forecasted demand from the EV industry and other advanced manufacturing applications, developing mining operations in the Ring of Fire continues to be a point of conversation amongst mining industry representatives and policy leaders. However, developing EV critical mineral mining and processing facilities in such a remote region of Northern Ontario presents significant challenges, including the distances involved in transporting personnel and equipment and the lack of existing infrastructure required to sustain mining operations.

Developing mining operations in the Ring of Fire also risks inducing negative environmental impacts in this ecologically sensitive region. Furthermore, for critical mineral resources to be developed in the Ring of Fire, it would be essential for Indigenous communities in Northern Ontario to support exploration and development.[64] Co-ownership would be obligatory for such a development. The region is home to nine First Nations representing 33 First Nation communities.[65] For these reasons, it is not clear at present if Ontario will develop its domestic supply of critical mineral resources in the area.

UPSTREAM LABOUR SUPPLY AND DEMAND

This section explores the intersection of supply and demand for talent in the upstream, critical minerals mining and processing segment of the EV value chain. Most of the roles explored in this section relate to the exploration, mining, and processing of critical minerals. However, some of the roles discussed in this section are not exclusive to upstream activities and may be needed for other segments of the EV value chain—or other sectors of Ontario's economy entirely.

61 Ontario Mining Association, "OMA-OLMP Labour Market Assessment," IPSOS, November 14, 2023, 8, https://oma.on.ca/Ipsos_OMA-OLMP-Research-Project_Final-Report_Nov-14_English.pdf

62 Government of Canada, "The Canadian Critical Minerals Strategy: Powering the Green and Digital Economy for Canada and the World," 2022, https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html

63 Government of Ontario, "Ontario's Ring of Fire," last updated November 1, 2022, https://www.ontario.ca/page/ontarios-ring-fire

64 "First Nations forge alliance as Ontario's rush for critical minerals sparks alarm," Financial Post, February 2, 2023, https://financialpost.com/commodities/mining/ontario-first-nations-alliance-over-mining-concerns

65 Margarita Todorova, Micah Lanez, & Maya Ordoñez, "Ontario Mining and Toronto's Global Reach 2024," Global Business Reports (Pre-Release Edition), November 20, 2023, https://www.gbreports.com/files/pdf/_2023/Ontario-2024-Prerelease-231204.pdf, 9; WCS Canada, "Ring of Fire," 2022, https://wcsringoffire.ca/communities/

Upstream critical minerals mining and processing roles include jobs like geologists, geological technicians, geomatics professionals, metallurgical, materials, and mining engineers, chemists and chemical engineers, drillers and blasters, and machine and plant operators for mineral and metal processing, to name a few. There are, in fact, many roles required to bring exploration, mining, and processing of critical minerals to market and a sufficient supply of skilled talent in these roles is needed to meet demand.

There are many factors that can influence the supply of talent. As mentioned, competition for the same types of talent is one—and one that can become more salient when there is a general labour shortage. Other factors specific to the mining sector are proximity and public perception of the industry. First, in terms of proximity, most of Ontario's major mining projects are in the northern regions of the province. These sparsely populated areas do not possess the same volume of talent that is available in Ontario's southern regions. Thus, there may be few candidates with the required skills and competencies available for any given open job.

Second, some segments of Ontario's population have negative perceptions of the mining industry, such as mining being associated with environmental harm. These negative perceptions may direct Ontario's workforce toward industries that are perceived more positively, such as those thought to be more sustainable. Further, there are documented stigmas associated with certain types of work, a phenomenon regularly noted for skilled trade-related roles, that may contribute to a muted supply of available talent.[66]

Across Ontario, 19 of 23 universities and 24 colleges have world-class programs in mining, earth and environmental sciences, and engineering.[67] Ontario graduates 63,500 students in STEM fields each year, supporting the pipeline of talent required to build Ontario's critical minerals workforce.[68] However, recent research has noted that occupations within the mining industry that have the most qualification requirements also face the highest retirement rates,[69] meaning that workers who are critical to the success of mining operations are in dire demand and will continue to be highly demanded for years to come. Additionally, the number of mining and mineral engineering graduates across Canada dropped by 37% between 2016 and 2021, while graduates from geoscience programs dropped by 43% in the same timeframe.[70]

In response to ICTC's employer survey, respondents from the mining sector held mixed views about whether there was a sufficient supply of new graduates available to meet their talent needs. A quarter of respondents indicated that there are not enough graduates entering the mining industry, while 32% indicated that there are only "a few new graduates" entering the industry. Another 32% of respondents reported that there are "lots of new graduates" entering the mining industry in Ontario (see Figure 3 below).

66 See: Erik Henningsmoen, Todd Legere, Heather McGeer, & Justin Ratcliffe, "Equitable Recovery and New Frontiers: Understanding Demand and Supply in Manufacturing, Construction, Retail, and Hospitality," Information and Communications Technology Council (ICTC), April 2023, https://ictc-ctic.ca/reports/equitable-recovery-and-new-frontiers, 68

67 "Mining," Invest Ontario, September 29, 2023, https://www.investontario.ca/mining#related

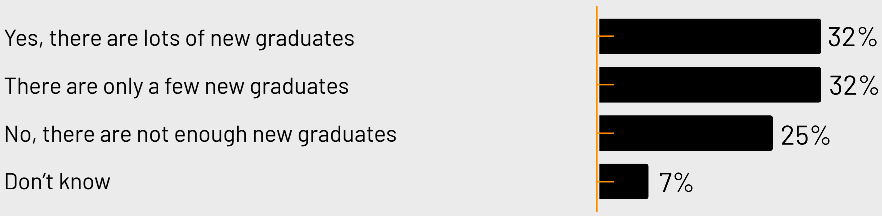
68 https://www.ovinhub.ca/wp-content/uploads/2022/09/QSR-Critical-Minerals-for-EV-Mini-Booklet-Final.pdf

69 Ontario Mining Association, "OMA-OLMP Labour Market Assessment," IPSOS, November 14, 2023, https://oma.on.ca/Ipsos_OMA-OLMP-Research-Project_Final-Report_Nov-14_English.pdf, 7.

70 When assessing undergraduate equivalents and below, see: Statistics Canada. Table 37-10-0183-01 Postsecondary graduates, by detailed field of study and International Standard Classification of Education, https://doi.org/10.25318/3710018301-eng

Figure 3: Mining: Are There Enough Graduates Entering the Industry?

MINING: ARE THERE ENOUGH GRADUATES?



Source: ICTC EV industry Employer Survey. (N=28)

On the question of talent shortfalls in particular mining occupations, interviewees noted that metallurgical engineers and mining and mineral engineers are anticipated to fall short of labour needs in the short to medium term. Interviewees noted that the pipeline of these engineers heavily fluctuates with the corresponding macroeconomic conditions. This can be seen when viewing the graduate count after the 2008 crisis, and in the current reality of the post-pandemic economic environment in Ontario. Interviewees observed that individuals who have an interest in studying metallurgical engineering or geoscience often seek alternative engineering-focused career pathways that aren't as volatile.

Survey respondents were also asked how the build-out of the EV industry is likely to affect their business. A few of these questions were directly related to their talent needs, while others were about things that indirectly impact talent. For instance, an increase in demand for products and services can indirectly affect the need for various types of talent. Overall, most respondents believed that the build-out of Ontario's EV industry would have beneficial impacts on their respective companies and the mining industry as a whole; see Figure 4.

Figure 4: Mining Sector: Favourable Outcomes Associated with EV Ecosystem Development

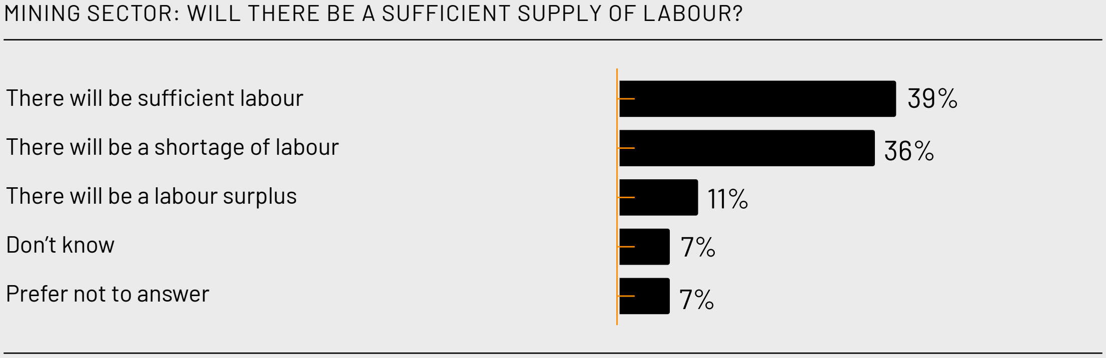
MINING: INVESTMENT IN ONTARIO'S EV INDUSTRY WILL HAVE A FAVOURABLE IMPACT ON...

Source: ICTC EV industry Employer Survey. (N=28)

The majority of respondents (73%) reported that investment in the EV industry would improve the number of people available to work and would have a favourable effect on the types of skills and talent their business would need (90%). However, respondents were split about whether it would improve the quality of the talent their firm has access to (50%). As noted by a few interviewees, some parts of the public consider Ontario's mining industry unfavourably. For many people, there is a disconnect between the resources they consume in their day-to-day lives and where these materials originate.

Respondents were then asked whether they think there will be a sufficient supply of labour with the skills needed to meet industry demand. Eleven percent of respondents felt there would be a labour surplus, and 39% felt there would be a sufficient supply of labour. However, 36% of respondents believed there would be a shortage of labour; see Figure 5 below.

Figure 5: Mining Sector: Will There Be a Sufficient Supply of Labour?



Data source: ICTC EV industry Employer Survey. (N=28)

In addition to conducting interviews and an employer survey, ICTC used insights from its primary and secondary research to map Statistics Canada's National Occupational Classifications (NOC) codes to known occupations in the upstream segment of the EV value chain (see Table 5).[71] This enabled ICTC to use Statistics Canada's Labour Force Survey to track employment in upstream EV occupations in Ontario over time, as well as the unemployment rate for Ontario's upstream labour force. While many of the NOC codes pertain to both critical minerals mining and mining for other types of natural resources, many of the skills and competencies that are needed for critical minerals mining roles are similar to those of other types of mining. Still, some of the knowledge and skills will be unique to each segment of the mining industry.

71 See: Javier Colato & Lindsey Ice, "Charging into the future: the transition to electric vehicles," US Bureau of Labour Statistics, Beyond the Numbers, vol. 12, no. 4, February 2023, https://www.bls.gov/opub/btn/volume-12/charging-into-the-future-the-transition-to-electric-vehicles.htm; James Hamilton, "Careers in Electric Vehicles," US Bureau of Labor Statistics, September 2011, https://www.bls.gov/green/electric_vehicles/electric_vehicles.pdf, 5-12; Shannon M. Sedgwick & Christine Cooper, "Electric Vehicles: The Market and Its Future Workforce Needs," Los Angeles County Economic Development Corporation, August 2012, https://www.pacific-gateway.org/ev_pgwin_final.pdf, 33; "Electric Vehicle-Battery Value Chain Talent Requirements," Invest Windsor/Essex, December 2021, https://www.workforcewindsoressex.com/wp-content/uploads/2021/12/Electric-Vehicle-Battery-Value-Chain-Talent-reduced.pdf

Table 5: NOC Codes and Job Titles Pertaining to the Upstream Component of the EV Value Chain

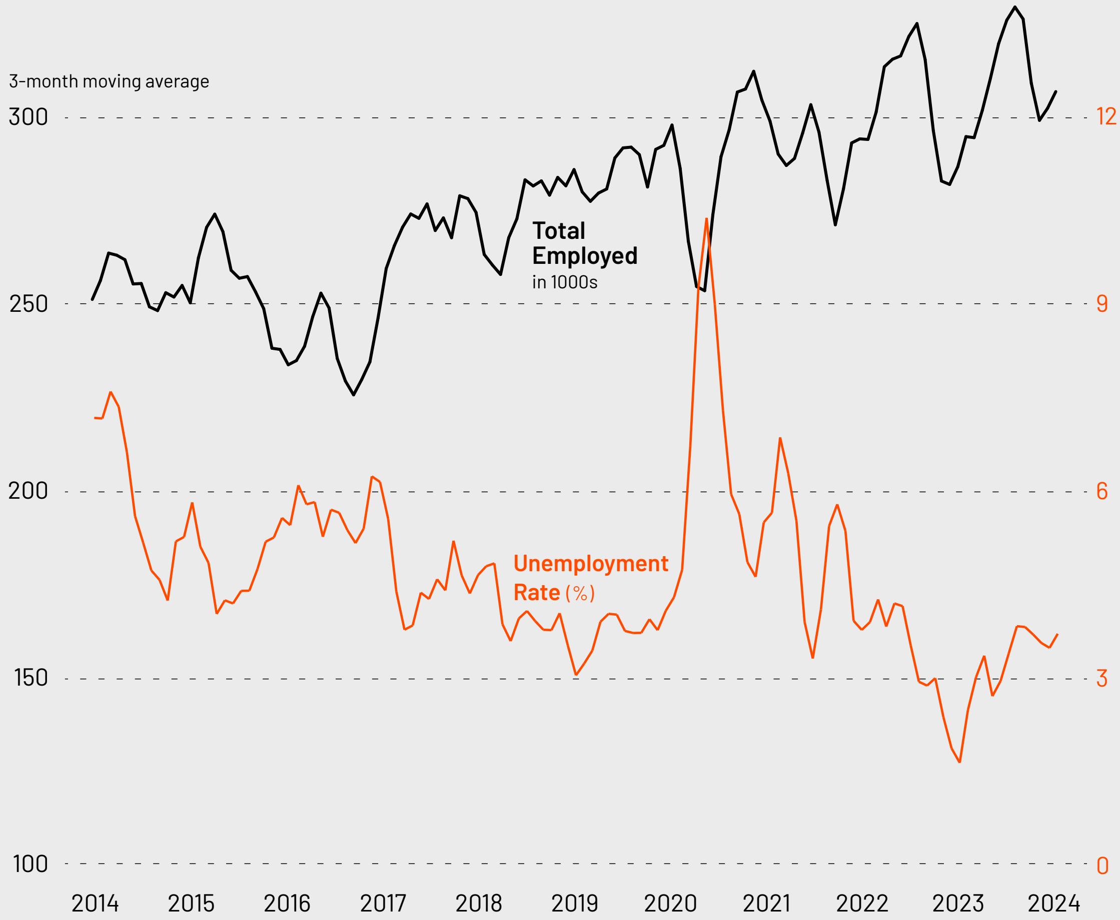
NOC CODES	
21101	Chemists
21102	Geoscientists and oceanographers
21109	Other professional occupations in physical sciences
21301	Mechanical engineers
21320	Chemical engineers
21330	Mining engineers
21331	Geological engineers
21322	Metallurgical and materials engineers
22101	Geological and mineral technologists and technicians
22312	Industrial instrument technicians and mechanics
72101	Tool and die makers
72200	Electricians (except industrial and power system)
72201	Industrial electricians
72203	Electrical power line and cable workers
72400	Construction millwrights and industrial mechanics
72405	Machine fitters
75101	Material handlers
83100	Underground production and development miners
94100	Machine operators, mineral and metal processing
94110	Chemical plant machine operators
95102	Labourers in chemical products processing and utilities

JOB TITLES
Blaster
Chemical Engineer
Chemist
Crane Mechanic
Crane Operator
Driller
Ecologist
Environmental Engineer
Exploration Geologist
Field Quality Engineer
General Labourer
Geological Technician
Geologist
Geomatics Professional
Machine Operator
Machine Technician
Material Handler
Materials Engineer
Metallurgical Engineer
Mechanical Journeyperson
Millwright
Mineralogist
Mining Engineer
Mining Geologist
Pipefitter
Planning Engineer
Plant Operator
Vehicle Operator

Data source: NOC Codes identified using Statistics Canada, ICTC analysis.
Job titles identified using secondary data sources, ICTC analysis.

Given that there is a growing demand for critical minerals, it is important to explore the underlying labour force that could contribute to the supply of skilled talent to the critical minerals mining industry. While there are limitations to using this measurement as an accurate measure of supply, it works well as a proxy for the availability of talent. Figure 6 indicates the total number of people employed in roles relevant to the upstream in Ontario over time. The data shows an upward trend in the number of individuals working in upstream mining-related occupations from 2014 to 2024. It indicates that the number of jobs available in the upstream mining industry in Ontario is growing and that, to date, there has been a sufficient supply of talent with the right skills and competencies to fill more than 46,000 roles.

Figure 6: Ontario Residents in Engaged in Occupations Relevant to Upstream EV Value Chain



Data source: Statistics Canada Labour Force Survey, ICTC Analysis.

That said, Figure 6 also shows the unemployment rate for Ontario's upstream labour force over the last 10 years, demonstrating what percentage of the total labour force was unemployed and looking for work at any given time. In 2023, the unemployment rate was notably the closest that it has been to zero since 2014, suggesting that in 2023, employers hiring upstream talent would have faced considerable competition for new workers. With the right tools and policy levers, Ontario can direct this talent supply to meet the increased demand for talent in the mining industry.

The data also shows substantial volatility in the number of Ontario residents working in upstream mining-related roles. For example, from 2021 to 2023, the industry gained and then lost nearly 40,000 employees. Notably, this concern was also raised by employers and subject matter experts who were interviewed during this study. They mentioned that employment volatility in the mining industry makes career paths in the industry more uncertain than in other industries and, because of this, workers may seek employment in other industries where they can obtain more stable careers.[72]

72 See: Erik Henningsmoen, Todd Legere, Heather McGeer, Justin Ratcliffe, "Equitable Recovery and New Frontiers: Understanding Demand and Supply in Manufacturing, Construction, Retail, and Hospitality," 57.

CRITICAL MINERALS: WORKFORCE GAPS

The upstream stages of the value chain include three main activities related to critical minerals, namely exploration, extraction, and processing. Exploration involves searching for minerals that occur in concentrations and quantities high enough to justify mining infrastructure to be built.[73] Extraction entails mining the mineral, and processing refers to the activities that take place after the mineral is extracted from the ground, including separating, purifying, and converting the minerals into forms that can be used by manufacturers to make various products.

Exploration and Mining

Exploration and mining companies face challenges stemming from an aging workforce and an insufficient talent pipeline. An anticipated 50% of workers in the exploration and mining industry are expected to retire within the next decade.[74] Exploration and mining activities largely take place in Northern Ontario, often in remote locations. As exploration and critical mineral development projects are increasingly becoming commonplace, employers interviewed for this study noted that there could be an opportunity to develop a pool of available labour and more mining industry skills training based on region. This could increase short-term work opportunities for those residing in remote areas while providing a readily available labour pool for increased mining exploration efforts.

The cyclical nature of this industry has typically led companies to make decisions with short-term timelines, resulting in the difficulty of maintaining a consistent, skilled labour pool. Mining employment can be quite unstable as employment is closely linked to commodity cycles and the failure or success of individual exploration projects. Each individual mine has its own finite resource cycle, and changing employment levels are required throughout the lifecycle of the project.

As an executive in the mining industry notes on the cyclical and unstable nature of labour in the mining and exploration industry, "Sometimes you start a project, and it lasts for a year or two, and then it doesn't go anywhere. So, it's kind of difficult to maintain a working relationship, especially in the exploration phase."

Attracting youth to the mining industry is also challenged by jobs that are often perceived as unsafe, physically demanding, and damaging to the environment.[75] Interviewees echoed this sentiment of an aging workforce and difficulty in attracting young workers throughout all areas of the critical minerals value chain. However, they viewed the difficulties associated with attracting youth to the labour force as the most concerning factor in the industry's talent pipeline. Targeted efforts to develop programs toward upstream career awareness in the primary, secondary, and post-secondary education systems will be critical to developing an ample talent pipeline in the mining industry.

73 Government of Canada, "The Canadian Critical Minerals Strategy," 40.

74 Ontario Mining Association, "OMA-OLMP Labour Market Assessment," Ipsos, November 14, 2023, https://oma.on.ca/Ipsos_OMA-OLMP-Research-Project_Final-Report_Nov-14_English.pdf

75 Ontario Mining Association, "OMA-OLMP Labour Market Assessment," ISPOS, 68.

Canadian companies have generally lagged in advanced technological adoption, yet the mining industry has been at the forefront of incorporating technology in its operations.[76] However, mining industry interviewees noted that technology adoption by most post-secondary institutions is not being incorporated into learning outcomes quick enough and new hires are not graduating workforce ready.

This is especially troubling as post-secondary institutions have noted that the cyclical nature of the mining industry leads to an inconsistency of work-integrated learning (WIL) opportunities for students.[77] Yet WIL programming is important for ensuring new graduates receive opportunities to learn industry-standard technologies in vocational settings. A more collaborative approach between post-secondary institutions and industry is needed to ensure the skill sets of students graduating meet the needs of employers in the mining sector.

Exploration incentives from Ontario's critical mineral strategy are already proving successful in advancing exploration and development of mining projects across the province, with a noted 41% increase in 2022.[78] Interviewees noted how geologists and geoscientists are in high demand. With this high demand for earth science talent in mining, artificial intelligence (AI) is beginning to play a large role in modelling ore deposits. With the hiring demand for geologists complimented by both federal and critical mineral strategies, interviewees believed Ontario post-secondary institutions are well positioned to build robust and adaptable AI programs to compliment and make more efficient the diminishing number of geologists entering Ontario's mining sector. Yet, a number of interviewees noted that many geology programs across Canada do not leverage AI technology to its full potential and viewed this as an opportunity for further development.

Beyond exploration, the mining industry is rapidly developing broader AI models that can characterize and predict the performance of the entire mining value chain.[79] Ensuring that high-quality data standards are established will be key to the success of mining companies leveraging AI technologies.[80] Establishing successful partnerships with organizations that have implemented such technologies will be key to optimizing efficiencies through remote monitoring and minimizing labour needs. Interviewees noted how training institutions such as NORCAT could act as critical partners for achieving such AI implementation in the mining industry.

Interviewees engaged in mining activities noted the transition to using BEVs for underground mining. As battery capacity advances, employers anticipate cycling out vehicles and other mining equipment powered by ICEs due to the impact of exhaust fumes on underground ventilation. Although in the preliminary stages, employers noted that some mines are bringing electric-powered mining vehicles and machinery into service. BEV mining machinery requires specialized knowledge for service and maintenance, and OEMs are currently servicing these battery electric mining fleets, but a transition to in-house servicing at Ontario mining sites is anticipated in short order.

76 Statistics Canada, Table 27-10-0370-01 Adoption of additional advanced technologies, by industry and enterprise size, https://doi.org/10.25318/2710037001-eng; Mining Industry Human Resources Council, "Canadian Mining Labour Market: 10-Year Outlook," December 2019, https://mihr.ca/wpcontent/uploads/2020/03/MIHR_National_Report_web2.pdf

77 "Outlook 2023: Canadian Mineral Exploration HR," Mining Industry Human Resources Council & Prospectors & Developers Association of Canada, December 2023, https://mihr.ca/wp-content/uploads/2023/12/MiHR-Exploration-Report-2023-EN.pdf, 42.

78 Margarita Todorova, Micah Lanez, & Maya Ordoñez, "Ontario Mining and Toronto's Global Reach 2024," Global Business Reports, 9.

79 Ibid., 18

80 Andrew Swart, Shak Parran, & Don Duval, "Future of mining with AI: Building the first steps towards an insight driven organization," Deloitte, 2018, https://www2.deloitte.com/content/dam/Deloitte/es/Documents/energia/Deloitte-ES-Energia-Futuro-Mineria-Inteligencia-Artificial.pdf, 6.

Minerals Processing

In general, Canada's critical mineral processing capabilities are quite limited as most raw mineral resources are exported abroad for processing. Ontario will need to further critical minerals processing and refining investments to meet market demand in upstream portions of the EV value chain. With the insufficient capacity of critical mineral refining in Ontario, developing efficient refining processes and scaling them to serve production demands will be a monumental task that requires investment in infrastructure, research, and human capital to overcome technological challenges and achieve competitive production levels. This refining capacity gap represents a weak point in Ontario's EV value chain.

Mining industry interviewees anticipate that vertical integration will be increasingly pursued due to challenging financial markets and the immediate push for independence of domestic critical minerals processing. Incentives to support innovative financing methods should be further explored. In short, technological advancements in critical mineral processing play a pivotal role in advancing the EV supply chain in Ontario. To scale the critical mineral processing workforce to meet the future needs of the province's EV industry, a coordinated approach between the private sector, post-secondary institutions, and government is required to ensure workforce development initiatives are specific and robust enough to respond to industry needs.

76 Statistics Canada, Table 27-10-0370-01 Adoption of additional advanced technologies, by industry and enterprise size, https://doi.org/10.25318/2710037001-eng; Mining Industry Human Resources Council, "Canadian Mining Labour Market: 10-Year Outlook," December 2019, https://mihr.ca/wpcontent/uploads/2020/03/MIHR_National_Report_web2.pdf

77 "Outlook 2023: Canadian Mineral Exploration HR," Mining Industry Human Resources Council & Prospectors & Developers Association of Canada, December 2023, https://mihr.ca/wp-content/uploads/2023/12/MiHR-Exploration-Report-2023-EN.pdf, 42.

78 Margarita Todorova, Micah Lanez, & Maya Ordoñez, "Ontario Mining and Toronto's Global Reach 2024," Global Business Reports, 9.

79 Ibid., 18

80 Andrew Swart, Shak Parran, & Don Duval, "Future of mining with AI: Building the first steps towards an insight driven organization," Deloitte, 2018, https://www2.deloitte.com/content/dam/Deloitte/es/Documents/energia/Deloitte-ES-Energia-Futuro-Mineria-Inteligencia-Artificial.pdf, 6.

PART III

MIDSTREAM

The midstream phase of the EV value chain begins with EV battery component manufacturing and battery pack assembly. Manufacturing EV batteries requires advanced technologies and precise assembly processes to ensure optimal performance and safety.[83] Following battery component manufacturing is battery assembly, EV parts manufacturing and final vehicle assembly. In this phase of the EV value chain, various inputs, such as batteries, electric motors, power electronics, chassis, and body panels, are produced and then integrated into final vehicle assembly.[84] The assembly process requires careful design, process control, quality assurance, and testing to ensure that all components are correctly installed and function in a new EV as intended.

The manufacturing and assembly phase is supported by preceding research and development (R&D) and design activities, which may take place at a larger scale in Ontario in the future. Experts interviewed note that much of this automotive design and R&D work takes place in regions such as the United States, the European Union, and Japan at present. These activities are crucial for driving innovation in EV technology, improving performance, efficiency, and safety, and meeting evolving consumer demands. Once an EV is completely assembled, it is sold through a sales and distribution network to the final consumer.

BATTERY PRECURSORS & EV BATTERY MANUFACTURING

Overview of Battery Precursor & EV Battery Manufacturing

Following mining, raw materials are refined and then, in the midstream phase, are converted into battery precursors with the requisite purity levels essential for battery applications: processes such as leaching, precipitation, and electrolysis are used to eliminate impurities that could compromise battery performance and safety.[85]

Battery precursors serve as the primary raw materials essential to produce cathode active materials (CAM), which are integral for rechargeable lithium ion batteries. The quality and characteristics of these materials directly influence the performance and properties of the final battery. Diverse precursor materials, including lithium cobalt oxide, lithium manganese oxide, lithium iron phosphate, and lithium nickel cobalt manganese oxide, exist.[86] Each precursor material has a distinct balance of thermal stability, energy density, power density, and cycle life. However, advancements in battery precursor technology, especially in nanomaterials and solid-state batteries, are fostering innovations to enhance the lifecycle of precursor materials.[87]

After mineral refining, cathode and anode active materials are produced. According to Invest Canada, cathodes make up approximately 51% of the total cost of an EV battery.[88] The cathode material is derived from a blend of lithium and other metals like nickel, manganese, and cobalt, while the anode active material (AAM) originates from graphite applied to a copper foil.[89]

83 Husain, Iqbal. Electric and hybrid vehicles: design fundamentals. CRC press, 2021.

84 Ibid.

85 Jingshan Li, Shiyu Zhou, & Yehui Han (eds.), Advances in battery manufacturing, service, and management systems, John Wiley & Sons, 2016, 3.

86 Hongxu Dong & Gary M. Koenig. "A review on synthesis and engineering of crystal precursors produced via coprecipitation for multicomponent lithium-ion battery cathode materials." CrystEngComm 22, no. 9 (2020): 1514-1530

87 Ibid.

88 Invest Canada, "Understanding Canada's EV supply chain in 60 seconds (video)," accessed March 13, 2024, https://www.investcanada.ca/industries/ev-supply-chain

89 Wayne Cai, "Lithium-Ion Battery Manufacturing for Electric Vehicles: A Contemporary Overview." Advances in Battery Manufacturing, Service, and Management Systems (2016): 1-28.

The CAM manufacturing process includes multiple intricate stages. First, metal sulphates are transformed into hydroxides; this is followed by solid precipitation, filtration, rinsing, and blending with lithium hydroxide.[90] The mixture then undergoes high-temperature oxygenation to produce CAM. Critical purification steps are integral to meeting stringent material standards for CAM, including eliminating particulate contaminants from metal sulphate solutions and reagents, gathering CAM precursor solids, and purifying gases.[91] The use of high-efficiency, absolute-rated filters during production ensures the purity and consistency of cathode materials, meeting the precise requirements of EV battery manufacturers.[92]

The subsequent phase is battery cell manufacturing, during which the fundamental units of an EV battery, comprising the anode, cathode, separator, and electrolyte, are enclosed and encased.[93] Following cell manufacturing, the battery modules are assembled. These modules may include necessary electronics or systems to manage the cell environment, such as sensors and voltage regulators.[94] During this stage, individual cells are grouped together in series or parallel configurations.

Battery pack assembly marks the final stage in the manufacturing process. Assembled modules are integrated into a unit within a battery pack enclosure.[95] This pack includes both a cooling system to regulate temperature and a battery management system to monitor performance. The battery pack is then integrated into the vehicle during assembly, along with various other components, such as the electric motor, power management unit, and other electrical systems.[96]

This complex manufacturing process requires skilled labour to be carried out successfully, including engineers with backgrounds in battery cell technology, manufacturing, material science, and quality control. It also requires skilled technicians, production planners, team/line assemblers, and machine operators. The ALBATTS project, an EV battery research initiative funded by the European Union (EU), provides a useful high-level overview of EV battery manufacturing roles; see Table 6.

90 Battery Precursor Materials: https://www.aichelin.at/en/products/topics/battery-precursor-materials

91 Ibid.

92 Bin Huang, et al., "Layered cathode materials: Precursors, synthesis, microstructure, electrochemical properties, and battery performance," Small 18, no. 20 (2022): 2107697.

93 Ibid.

94 Jingshan Li, Shiyu Zhou, & Yehui Han (eds.), Advances in battery manufacturing, service, and management systems. John Wiley & Sons, 2016.

95 Ibid.

96 Ibid.

Table 6: Jobs/Roles Across the EV Battery Manufacturing Process

RAW MATERIALS AND PROCESSING	COMPONENTS/CELL MANUFACTURING	MODULE AND PACK MANUFACTURING	BATTERY INTEGRATION
Battery material engineer	Battery design engineer	Battery design engineer	Battery system engineer
Production engineer	Manufacturing engineer	Formation maintenance manager	Embedded system engineer
Material planner	Cell assembly process engineer	Battery pack engineer	Software developer
Material handler	Production assembly operator	Cell module engineer	Test engineer
Machine operator	Battery specialist	Simulation engineer	Quality specialist
Supply chain manager	Machine operator	Machine operator	Application engineer

Source: Adapted from Jakub Stolfa, "Emerging skills needs from ALBATTS project on the battery value chain and related initiatives," in *Skills and Education for the Emerging Battery Economy: European Challenges and Solutions*, June 2021, https://energy.ec.europa.eu/system/files/2021-06/education_skills_presentations_0.pdf, 53.

High-level competencies required for EV battery manufacturing include traditional manufacturing skills such as production planning and industrial design but also require significant expertise in fields such as battery materials and electronic systems, materials sciences and electrochemistry, and quality control and testing. Significant digital skills, such as data science and software development, are also involved in successfully manufacturing EV batteries. Again, the EU-funded ALBATTS project provides an overview of core, high-level competencies in the EV battery manufacturing process; see Table 7.

Table 7: Competencies Across the EV Battery Manufacturing Process

RAW MATERIALS AND PROCESSING	COMPONENTS/CELL MANUFACTURING	MODULE AND PACK MANUFACTURING	BATTERY INTEGRATION
Resource management	Battery cell design	Industrial design	Battery management systems
Materials science	Volume production	Mechanical engineering	Data science
Battery materials	Battery fluids	Additive technology	Software development
Production processes	Cell testing	Module and pack design	Cooling systems
Electrochemistry	Battery components	Development of models	Product requirements
Manufacturing and processing	Quality/ inspection	Process improvement	Product testing

Source: Adapted from Jakub Stolfa, "Emerging skills needs from ALBATTS project on the battery value chain and related initiatives," in *Skills and Education for the Emerging Battery Economy: European Challenges and Solutions*, June 2021, 51.

EV Battery Manufacturing in Ontario

A 2022 report from Clean Energy Canada estimates that Canada has the potential to build a domestic EV battery supply chain, which could support up to 250,000 direct and indirect jobs by 2030 and add $48 billion to the Canadian economy annually.[97] This EV battery supply chain would be centred on the significant EV battery materials and assembly infrastructure currently under development in Ontario and Quebec. Ontario's share of this battery infrastructure includes two large battery plants in St. Thomas and Windsor, ON, which are expected to require a combined 5,500 workers and support thousands of indirect jobs in supporting industries.[98] Furthermore, a battery materials plant in Loyalist Township, ON, will require 600 workers once fully operational.[99] Some industry experts interviewed as part of this study noted that there are likely more strategic investments in EV battery manufacturing forthcoming as Ontario's EV ecosystem expands.

The Geopolitics of the EV Battery Supply Chain and Prospects in Ontario

The global EV battery supply chain faces challenges, including mineral deposits being concentrated within a few specific regions of the world, vulnerability to extreme weather events and natural disasters, and the potential for geopolitical tensions. The essential lithium and cobalt reserves vital for EV battery production are concentrated in a select group of countries across South America, Asia, and North America.[100] Chile and Argentina alone hold 50% of the world's lithium reserves, while China, a major player in cobalt reserves, refines nearly half of the world's lithium, relying heavily on imports for this resource.[101]

The Asia-Pacific region stands out as a hub for EV parts and components market expansion, showcasing the highest compound annual growth rate and the highest increase in revenue share.[102] Moreover, China currently dominates the EV battery supply chain globally.[103] This geographically dispersed supply chain subjects the world's EV supply chain to increased risk—disruptions in the supply chain can lead to bottlenecks, increased transportation costs, job losses, and hindered decarbonization efforts in the transportation sector. Efforts to bolster domestic EV battery production are aimed at mitigating dependency risks and diversifying supply chain sources, aligning with the goal of de-risking rather than de-coupling from global supply chains.[104]

97 Clean Energy Canada, "Canada's New Economic Engine: Modelling Canada's EV battery supply chain potential—and how best to seize it," Clean Energy Canada & Trillium Network for Advanced Manufacturing, September 2022, https://cleanenergycanada.org/report/canadas-new-economic-engine/, 1.

98 "Volkswagen's New Electric Vehicle Battery Plant Will Create Thousands of New Jobs (Press Release)," Government of Ontario, https://news.ontario.ca/en/release/1002955/volkswagens-new-electric-vehicle-battery-plant-will-create-thousands-of-new-jobs; "Need a charge? Canada's $5-billion battery plant is looking for employees," Financial Post, August 16, 2023, https://financialpost.com/commodities/energy/electric-vehicles/nextstar-battery-plant-hiring

99 "New eastern Ontario plant to add hundreds of jobs, create battery components," CBC News, October 16, 2023, https://www.cbc.ca/news/canada/ottawa/new-electric-vehicle-battery-plant-loyalist-township-1.6997613

100 Pravin Kumar, et al., "Analyzing challenges for sustainable supply chain of electric vehicle batteries using a hybrid approach of Delphi and Best-Worst Method." Resources, Conservation and Recycling 175 (2021): 105879.

101 Ibid.

102 Bruno Jetin, "Who will control the electric vehicle market?" International Journal of Automotive Technology and Management 20, no. 2 (2020): 156-177.

103 "China's Stranglehold on EV Supply Chain Will Be Tough to Break," Bloomberg, September 27, 2023, https://www.bloomberg.com/graphics/2023-breaking-china-ev-supply-chain-dominance

104 Jade Rodysill & Sven Dharmani, "Why global industrial supply chains are decoupling," EY, June 2022, https://www.ey.com/en_nz/automotive-transportation/why-global-industrial-supply-chains-are-decoupling

Strengthening the EV battery supply chain through partnerships, regulations, domestic production, and circularity initiatives will benefit global economies by fostering economic opportunity, job creation, and EV supply chain accessibility. Ontario's strategic location offers access to ethically sourced minerals crucial for creating sustainable products. This reflects the trend of international automotive companies investing heavily in EV battery manufacturing facilities in the province, capitalizing on Canada's abundant mineral resources, as noted in previous sections. These planned investments are expected to bolster Canada's effort to achieve sustainable battery production to power its EV transition.

Ontario's expertise in cathode and anode production further bolsters its position in the EV parts supply chain. With industry expertise, extensive trade agreements, and access to abundant minerals, Ontario emerges as a cost-effective and globally connected hub for cathode manufacturing. Umicore's $1.5 billion investment in Ontario for cathode active battery material manufacturing underscores the province's strategic advantage in this domain.[105]

105 Clean Energy Canada, "Canada's New Economic Engine: Modelling Canada's EV battery supply chain potential—and how best to seize it," 2022, https://cleanenergycanada.org/wp-content/uploads/2022/09/CanadasNewEconomicEngine_Web.pdf

AUTOMOTIVE MANUFACTURING IN ONTARIO: THE HISTORICAL CONTEXT

The emerging EV industry in Ontario builds on a long legacy of automotive manufacturing spanning over a century. Since the early 1900s, automotive manufacturing has been spearheaded by large firms such as Ford and General Motors Canada in hubs such as Windsor and Oshawa, ON, as well as numerous smaller companies which have supplied these larger manufacturing firms with raw materials, parts, and services.[106] Automotive manufacturing has been a key source of employment, technological advancement, and prosperity in Ontario for decades.

In the early days of automotive manufacturing in Ontario, two pivotal national policies—the National Policy (1878) and the Imperial Preference (1932)—catalyzed the sector's growth. They attracted American manufacturers seeking to bypass cross-border tariffs and leverage preferential trade rates.[107] This strategic manoeuvre not only facilitated economies of scale but also entrenched American investment in the province.[108]

Despite challenges, including tariff fluctuations and market shifts, agreements like the Canada-US Auto Pact (1965-2001) and the North American Free Trade Agreement (NAFTA) (1994-2020) underpinned Ontario's status as a North American automotive manufacturing hub. Over the decades, the province became home to numerous assembly plants operated by major automakers such as Ford, General Motors, Chrysler (now Stellantis), Honda, Toyota, and others.[109] These plants produced a wide range of vehicles, including light-duty passenger cars, SUVs, and trucks, as well as commercial vehicles.

In recent years, the automotive sector in Ontario has undergone significant transformation. There has been a growing emphasis on innovation, research, and development, particularly in verticals related to EVs, autonomous driving technology, and connected vehicles. Ontario is positioning itself as a key player in the global transition to EVs and other alternative fuel vehicles.

Despite this progress, recent years have seen a downturn in automotive assembly jobs, driven by automation, technological strides, and global competition. While motor vehicle manufacturing historically bolstered Canada's GDP, climbing from $6.2 billion in 2010 to $7.25 billion in 2016, this growth eased and then reversed to $6.46 billion by 2019.[111] The annual output for the automotive industry declined by 22.7% in 2020 due to the global semiconductor chip shortage and supply chain disruptions stemming from the COVID-19 pandemic, which hindered production at many of Ontario's motor vehicle assembly plants.[112]

Despite these challenges, there is a noticeable resurgence in Ontario's automotive sector. Many of the industry experts that ICTC engaged for this study discussed the potential for a sectoral rebound, hinted at by the significant investments that are pouring into the region, as well as the new, duty-free incentives for originating vehicles and parts introduced under CUSMA.[113]

However, interviewees in this study also stressed that continued government support and policy initiatives will play a pivotal role in whether the industry's growth trajectory continues. Incentives for EV adoption, funding for R&D, and measures to attract investment and bolster industry competitiveness are indispensable. Nonetheless, Ontario's automotive sector remains a pivotal component of the provincial economy, brimming with opportunities for expansion and innovation.

106 Cameron Roberts, James Meadowcroft, & David Layzell, "The Rise of the Automobile: Lessons from Historical Canadian Transportation Transitions." Transition Accelerator Reports 2, no. 4, 2020, https://transitionaccelerator.ca/reports/the-rise-of-the-automobile-lessons-from-historical-canadian-transportation-transitions/, 1-35.

107 Stewart Melanson, "Learning from the Past-Volume 1: The Automotive Industry and Economic Development in Ontario; a historical Perspective (1904 to the Present)," Martin Prosperity Institute, Rotman School of Management, University of Toronto, 2009, https://www-2.rotman.utoronto.ca/mpi/wp-content/uploads/2009/02/Learning_from_the_Past_Vol_1_Auto-SMelanson.pdf

108 Ibid.

109 Brendan A. Sweeny, "Canada's Automotive Industry: A Decade in Review," Trillium Network for Advanced Manufacturing, 2020, https://trilliummfg.ca/wp-content/uploads/2020/05/TrilliumReport_AutoIndustry-DecadeInReview-May2020_2A.pdf, 3-6.

110 Brendan A. Sweeney, "Canada's Automotive Industry: Recession, Restructuring, and Future Prospects," New Frontiers of the Automobile Industry: Exploring Geographies, Technology, and Institutional Challenges, 2020, https://labordoc.ilo.org/discovery/fulldisplay/alma995076991602676/41ILO_INST:41ILO_V1, 67-88

111 Brendan A. Sweeny, "Canada's Automotive Industry: A Decade in Review," 2020, Trillium Network for Advanced Manufacturing, 3-6.

112 "Job Bank," Employment and Social Development Canada (Government of Canada), "Motor Vehicle, Body, Trailer, and Parts Manufacturing (NAICS 3361-3363): Ontario 2022-2024 [Sectoral Profile]," accessed May 19, 2023, https://www.jobbank.gc.ca/trend-analysis/job-market-reports/ontario/sectoral-profile-motor-manufacturing

113 Global Affairs Canada (Government of Canada), "Canada-United States-Mexico Agreement (CUSMA): Summary of Outcomes," last update January 28, 2020, https://www.international.gc.ca/trade-commerce/trade-agreements-accords-commerciaux/agr-acc/cusma-aceum/summary-sommaire.aspx?lang=eng

EV AUTOMOTIVE PARTS MANUFACTURING

Overview of EV Automotive Parts Manufacturing

The journey of EV components begins with conceptualization and design, where engineers and designers collaborate to innovate concepts for various components such as EV battery parts, electric motors, power electronics, transmissions, and charging systems. In this study, interviewees noted that given the complexity of EVs' electrical systems and sophisticated battery management, expertise in electrical engineering, energy storage, and power electronics is essential. The design process is shaped by extensive research, market analysis, and performance requirements to ensure alignment with customer needs, competitive landscapes, regulatory frameworks, technological environments, as well as aesthetic and socio-cultural considerations.[114]

Following design, prototypes are developed for testing and refinement. Prototyping enables manufacturers to assess functionality, performance, and safety, addressing potential issues through iterative design improvements. Materials such as steel, aluminum, composites, plastics, copper, lithium ion batteries, glass, and rubber are utilized in prototype construction to optimize performance, efficiency, and safety.[115]

As EV technology progresses, new materials and manufacturing techniques may be integrated to enhance performance and efficiency while reducing noise and weight. Selecting appropriate materials is crucial, with a focus on lightweight materials like advanced composites and high-strength alloys to improve efficiency and maximize range.[116]

Manufacturing techniques such as additive manufacturing, precision machining, and automated assembly lines facilitate the efficient production of complex components. Rigorous testing and validation procedures, including unique tests for EV battery performance and endurance, ensure compliance with regulatory standards and performance specifications.

The scaling up for mass production occurs in two phases: the new product introduction (NPI) phase and the ramp-up phase.[117] The NPI phase includes activities like design for manufacturing (DFM), process validation, and supplier qualification to optimize manufacturing efficiency and ensure a reliable supply chain. Once the NPI phase is complete, the focus shifts to ramping up production, which involves production capacity expansion, supply chain optimization, quality assurance, and continuous improvement measures.

114 Husain, Iqbal. Electric and hybrid vehicles: design fundamentals. CRC press, 2021.

115 Ibid.

116 Wen Zhang & Xu Jun, "Advanced lightweight materials for Automobiles: A review," Materials & Design 221 (2022): 110994.

117 "The Roadmap to Electric Vehicle Manufacturing," Acerta, last update February 5, 2024, https://acerta.ai/blog/roadmap-electric-vehicle-manufacturing

EV Automotive Parts Manufacturing in Ontario

The global EV parts and components market reached USD 168.9 billion in 2022 and is projected to soar to approximately USD 675.61 billion by 2032, boasting a compound annual growth rate of 14.87% from 2023 to 2032.[118] Ontario boasts a distinctive ecosystem within the global automotive landscape, with a rich history of over a century in meeting the diverse needs of international customers. The automotive cluster in Ontario encompasses a spectrum of expertise, spanning proof-of-concept prototyping, the automation of production line systems, and the development of cutting-edge technologies at research centres. Ontario's automotive corridor, stretching from Windsor to Ottawa, encompasses major players such as Ford, General Motors, Honda, Stellantis, Toyota, and Volkswagen.[119]

According to data from Invest Ontario, which details the province's automotive parts industry, some key statistics underscore the significance.[120] There are over 700 parts suppliers in the province, including over 400 companies involved in the development of connected and autonomous vehicles and solutions related to smart mobility.[121] The province boasts 500 tool, die, and mould makers, which contribute to 80% of production vehicles and parts exports globally. Additionally, four Ontario-based parts companies rank among the top 100 global suppliers.[122] Examples of leading automotive parts and OEM companies operating in Ontario include ArcelorMittal Dofasco, Blackberry QNX, Denso, Faurecia, Ford, GM, Honda, Lear, Linamar, Magna, Martinrea, Stellantis, Toyota, and Volkswagen.[123]

EV ASSEMBLY

Overview of EV Assembly

Once all the individual components of an EV have been designed and manufactured, different teams work together to assemble these components with the support of advanced robotics and automated systems. Chassis assembly takes place first. During this process, the vehicle's frame is constructed, along with the suspension system, brakes, and steering components.[124] Powertrain components, including the battery pack, are then installed, and electric motors are mounted directly onto the axles for propulsion. Finally, the vehicle's exterior body panels are formed, welded, painted, and assembled onto the frame.[125]

Once all the parts are assembled, the vehicle undergoes testing and quality assurance checks before being sent out for distribution and eventual sale to a consumer.[126] While sharing characteristics of traditional ICE vehicles, EV assembly differs in important ways. Several of the components that are used in EVs differ from those used in ICE vehicles and because of this, EV assembly facilities require specialized production lines for each EV model and key inputs, such as lightweight aluminum and advanced composite materials, electric motors and inverters, and battery modules.[127]

118 Fazel Mohammadi & Saif Mehrdad, "A comprehensive overview of electric vehicle batteries market," e-Prime-Advances in Electrical Engineering, Electronics and Energy (2023): 100127.

119 "Automotive," Invest Ontario, 2023, https://www.investontario.ca/automotive#intro.

120 Ibid.

121 Ibid

122 Ibid

123 Ibid.

124 c3controls, "Understanding the Design and Manufacture of Electric Vehicles – New Trends in Technology," accessed March 16, 2024, https://www.c3controls.com/white-paper/understanding-the-design-and-manufacture-of-electric-vehicles/

125 Ibid.

126 Ibid.

127 Iqbal Husain, *Electric and hybrid vehicles: design fundamentals*. CRC press, 2021.

EV Assembly in Ontario

Ontario stands as the hub of Canada's automotive industry, boasting vehicle assembly operations of five OEMs and several dozen other automotive companies. In 2022, the motor vehicles and parts manufacturing sector contributed $11.6 billion to Ontario's GDP, comprising 1.5% of the province's total economic activity.[128] Vehicle exports from Ontario dominated the provincial export landscape, accounting for a significant 13% of total goods exports at $13.2 billion, with an additional $15.1 billion from parts exports.[129] The past few years have witnessed significant investments in Canada's automotive sector, which is driven by large automotive manufacturers. Their combined commitments amount to nearly $15 billion, resulting in the creation of over 6,000 direct jobs and numerous opportunities across the supply chain.[130] A substantial portion of these investments is directed toward EV assembly and the development of the EV battery supply chain.

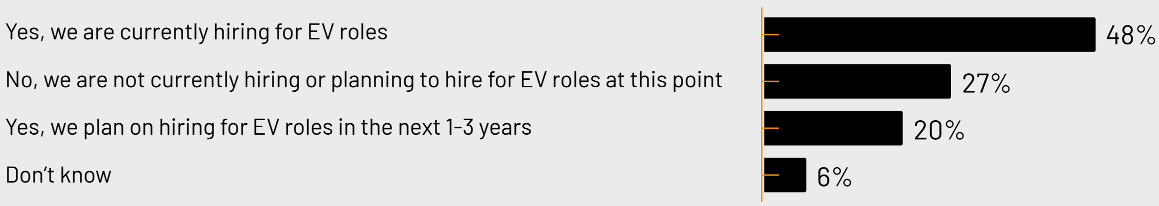
MIDSTREAM LABOUR SUPPLY AND DEMAND

This section looks at labour market trends in the midstream section of Ontario's EV value chain, which includes battery manufacturing, auto parts manufacturing, and vehicle assembly.

Survey respondents were asked whether they are currently hiring EV-related roles or plan to hire EV-related roles over the next one to three years. A majority (68%) of respondents from the midstream segment of the EV value chain indicated that they are hiring or plan to hire EV-related roles over the next three years, suggesting that the manufacturing sector is experiencing high demand for talent with EV-related skills. However, this percentage was slightly lower for midstream respondents than for respondents from other parts of the EV value chain. Eighty-three percent of respondents from the finance sector indicated that they are hiring or plan to hire EV-related roles, followed by 80% of materials recovery and recycling respondents.

Figure 7: EV Battery and Automotive Manufacturing: Hiring for EV-Related Roles

MIDSTREAM: HIRING FOR EV-RELATED ROLES



Data Source: ICTC EV Industry Workforce Survey. (N=71)

128 Canadian Vehicle Manufacturers Association, "State of the Canadian Automotive Industry," 2023, https://www.cvma.ca/wp-content/uploads/2023/12/State-of-the-Canadian-Automotive-Industry-2023.pdf

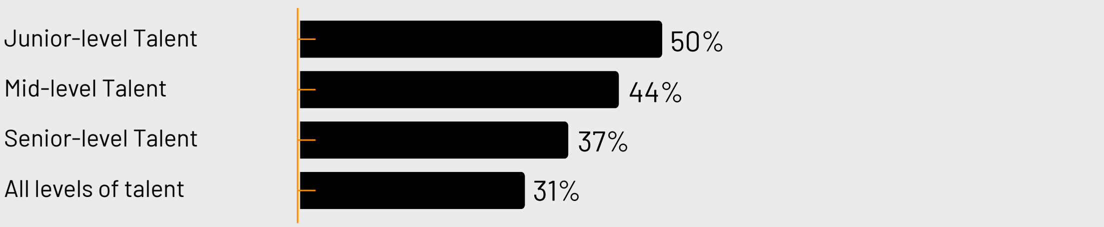
129 Ibid.

130 Ibid.

Survey respondents were also asked about the seniority level of EV talent they are hiring. Their responses suggest that demand for EV-related talent is not limited to specific seniority levels. Among midstream respondents who are currently hiring or planning to hire EV-related talent within the next one to three years, there is a high demand for workers at all seniority levels. Still, the most in-demand seniority level is junior-level talent, with half (50%) of respondents indicating that they are hiring or plan to hire this seniority level. This is followed by mid-level talent (44%) and senior-level talent (31%).

Figure 8: EV Battery and Automotive Manufacturing: Demand for Talent by Seniority

MIDSTREAM: DEMAND FOR SENIORITY



Data Source: ICTC EV Industry Workforce Survey. (N=52)

Survey respondents identified roles that are both in demand and specifically support Ontario's EV battery and vehicle manufacturing industries. Examples of roles associated with the design and engineering of EV vehicles and parts include manufacturing design roles, such as engineers, technicians, and supply chain managers, as well as R&D-focused roles, such as software developers, product managers, R&D engineers, R&D specialists, and information specialists. R&D was frequently mentioned as an in-demand competency, comprising analytical skills, technical skills, and knowledge of how to integrate emerging technologies, such as renewable and sustainable energy, into the existing manufacturing processes. Examples of roles associated with EV battery and vehicle assembly as well as EV part manufacturing include assemblers and technicians.

In addition to the employer survey, ICTC collected and analyzed publicly available job postings to track demand for EV manufacturing roles in Canada and the United States. As Ontario automotive manufacturers and parts suppliers are working to retool their production toward EVs and investing in new plants and equipment, most of the job postings captured pertain to EV manufacturing in the United States. However, as several new and retooled plants are slated to open in Ontario over the next few years, local demand for direct EV manufacturing roles will likely increase.

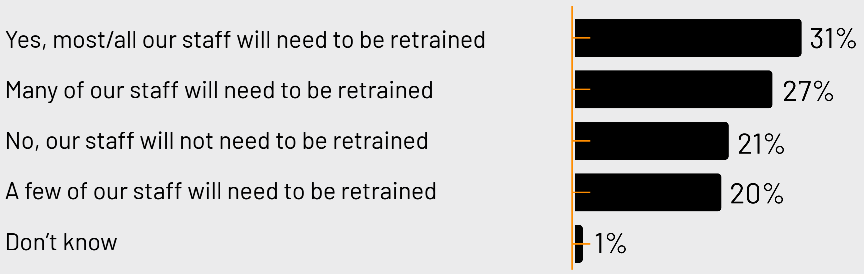
In terms of specific job titles, assembler was the most in-demand role by volume in the midstream manufacturing components of the EV value chain, followed by warehouse associate, assembly technician, general labourer, production associate, production worker, material handler, assembly worker, mechanical assembler, warehouse worker, and production assembler, pointing to the continued importance of assembly and general labour occupations in the automotive manufacturing sector.

While in the near to medium term, demand for manufacturing and operations is set to increase, over the long term, it is likely that a portion of these roles will be phased out as a result of AI and automation. In 2019, Canada's automotive manufacturing sector already had one of the highest robot densities in the world, with more than 1,475 installed robots per 10,000 manufacturing jobs.[131] Predictable, formularized physical manufacturing tasks are also some of the most at-risk tasks when it comes to automation, with it being possible to automate at least 64% of the hours that workers spend producing and assembling automotive vehicles.[132]

Returning to the employer survey, respondents were also asked whether their staff will need to be retrained as a result of the EV industry's expansion in Ontario. Responses to this question were mixed but still indicative of a need for retraining as the automotive sector evolves, with 58% of respondents indicating that either many, most, or all of their staff will need to be retrained, 20% indicated that just a few of their staff will need to be trained, and 21% indicated that none of their staff will need to be retrained; see Figure 9.

Figure 9: EV Battery and Automotive Manufacturing: Need for Staff Retaining

MIDSTREAM: WILL STAFF NEED TO BE RETRAINED FOR EV



Data Source: ICTC EV Industry Workforce Survey. (N=71)

Midstream respondents who indicated that their companies are not hiring or do not plan to hire EV-related roles were asked how easy they think it will be to reskill their existing workforce. Among these respondents 30% felt their workforce could easily or very easily be reskilled. Another 30% felt reskilling is possible, but only with dedicated investment.

In addition to conducting a survey, ICTC used insight from its primary and secondary research to map Statistics Canada's National Occupational Classifications (NOC) codes to known occupations in the midstream segment of the EV value chain (see Table 8).[133] This enabled ICTC to use Statistics Canada's Labour Force Survey to track employment in midstream roles in Ontario over time, as well as the unemployment rate for Ontario's midstream labour force.

131 "Canada's Automation and Robotics Landscape," Ngen, 2021, https://f.hubspotusercontent20.net/hubfs/5005023/Documents/TAP/Automation-and-robotics-NGen-Report.pdf

132 "Human + machine: A new era of automation in manufacturing," September 7, 2017, McKinsey & Company, https://www.mckinsey.com/capabilities/operations/our-insights/human-plus-machine-a-new-era-of-automation-in-manufacturing

133 See: Javier Colato & Lindsey Ice, "Charging into the future: the transition to electric vehicles," US Bureau of Labour Statistics, *Beyond the Numbers*, vol. 12, no. 4, February 2023; James Hamilton, "Careers in Electric Vehicles," US Bureau of Labor Statistics, September 2011, 5-12; Shannon M. Sedgwick & Christine Cooper, "Electric Vehicles: The Market and Its Future Workforce Needs," Los Angeles County Economic Development Corporation, August 2012, 33; "Electric Vehicle-Battery Value Chain Talent Requirements," Invest Windsor/Essex, December 2021.

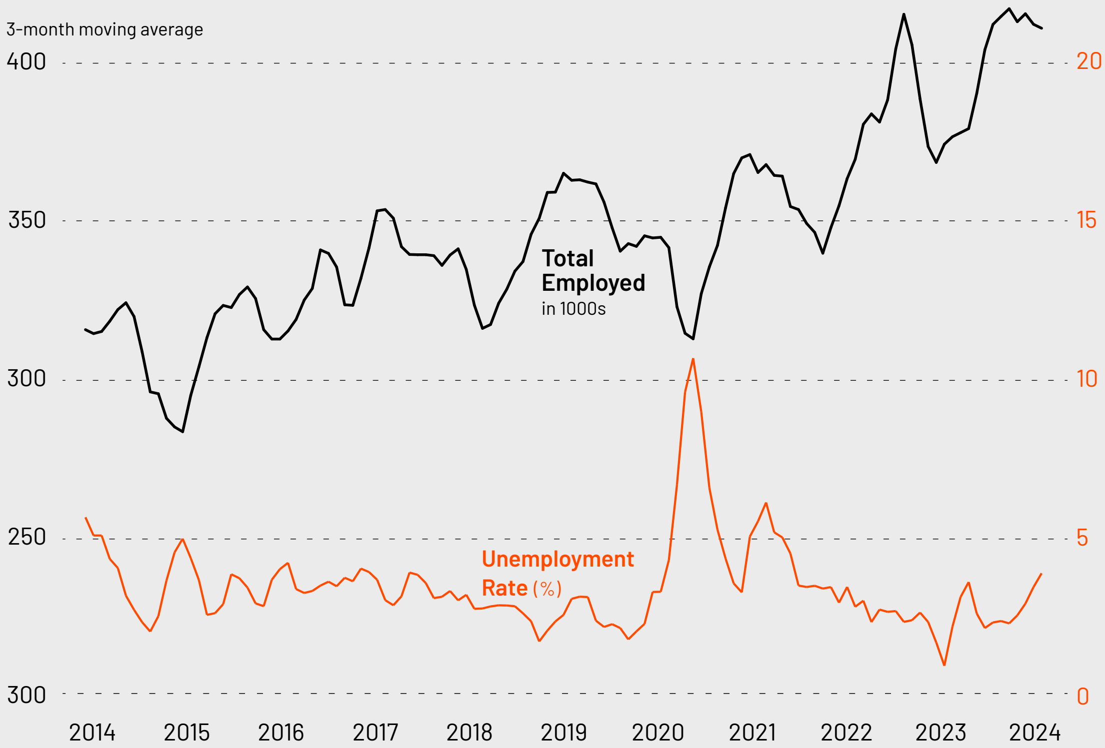
Table 8: NOC Codes and Job Titles Pertaining to the Midstream Component of the EV Value Chain

NOC CODES	JOB TITLES
20011 Architecture and science managers	Application Engineer
21101 Chemists	Assembler
21109 Other professional occupations in physical sciences	Assembly Technician
21202 Urban and land use planners	Assembly Worker
21221 Business systems specialists	Automation Engineer
21301 Mechanical engineers	Electrical Assembler
21310 Electrical and electronics engineers	Electrical Engineer
21320 Chemical engineers	Electrician
21321 Industrial and manufacturing engineers	Electronics Assembly Technician
22211 Industrial designers	Engineering Technician
22212 Drafting technologists and technicians	Design Engineer
22301 Mechanical engineering technologists and technicians	Chemist
22302 Industrial engineering and manufacturing technologists and technicians	Controls Engineer
22310 Electrical and electronics engineering technologists and technicians	Controls Technician
22312 Industrial instrument technicians and mechanics	Facilities Maintenance Technician
72011 Contractors and supervisors, electrical trades and telecommunications occupations	Forklift Operator
72100 Machinists and machining and tooling inspectors	General Labourer
72101 Tool and die makers	Industrial Electrician
72200 Electricians (except industrial and power system)	Industrial Engineer
72201 Industrial electricians	Maintenance Technician
72203 Electrical power line and cable workers	Manufacturing Engineer
72301 Steamfitters, pipefitters and sprinkler system installers	Manufacturing Technician
72400 Construction millwrights and industrial mechanics	Master Machinist
72405 Machine fitters	Material Handler
72422 Electrical mechanics	Mechanical Assembler
90010 Manufacturing managers	Mechanical Designer
90011 Utilities managers	Mechanical Engineer
92020 Supervisors, motor vehicle assembling	Mould maker
92021 Supervisors, electronics and electrical products manufacturing	Operations Manager
94200 Motor vehicle assemblers, inspectors and testers	Quality Engineer
94201 Electronics assemblers, fabricators, inspectors and testers	Quality Technician
94202 Assemblers and inspectors, electrical appliance, apparatus and equipment manufacturing	Repair Technician
94203 Assemblers, fabricators and inspectors, industrial electrical motors and transformers	Process Engineer
94204 Mechanical assemblers and inspectors	Production Assembler
94205 Machine operators and inspectors, electrical apparatus manufacturing	Production Associate
	Production Manager
	Production Technician
	Production Worker
	Systems Engineer
	Test Engineer
	Test Technician
	Tool and Die Maker
	Warehouse Associate
	Warehouse Worker

Data source: NOC Codes identified using Statistics Canada, ICTC analysis. Job titles identified using secondary data sources, ICTC analysis.

Figure 10 indicates the total number of people employed in midstream roles in Ontario over time, as well as the unemployment rate for Ontario's midstream labour force. Over the last 10 years, the number of individuals employed in midstream roles has increased, even as the unemployment rate has remained quite stable, suggesting that there is a reasonable supply of talent with the necessary skills and competencies to fill new roles. While manufacturing suffered during the early days of the pandemic,[134] sending individuals to other economic sectors, employment in midstream roles related to EV manufacturing has thrived in the post-pandemic period, increasing by over 65,000 employees.[135]

Figure 10: Ontario Residents in Engaged in Midstream Occupations Relevant to the EV Value Chain



Data Source: Statistics Canada Labour Force Survey, ICTC Analysis.

While there were more than 400,000 individuals working in Ontario's manufacturing sector as a whole in 2024, it is impossible to know from these data whether these individuals were working at firms involved in the manufacturing of EVs. For the EV manufacturing industry to maintain a secure talent pipeline, firms will need to incentivize individuals in other manufacturing roles to transition to the EV and wider automotive manufacturing industry. It is unclear whether there will be sufficient supply to meet the demand for talent in the midstream part of the EV ecosystem, so building out incentives and employment pathways will be important to ensuring the successful development of the midstream ecosystem.

134 Erik Henningsmoen, Todd Legere, Heather McGeer, Justin Ratcliffe, "Equitable Recovery and New Frontiers: Understanding Demand and Supply in Manufacturing, Construction, Retail, and Hospitality," 22–26.

135 Growth is over the period beginning January 2020, just prior to the pandemic and ending January 2024.

EV BATTERY, PARTS, AND VEHICLE MANUFACTURING: WORKFORCE GAPS

Despite growing employment in midstream EV roles, insights provided by interviewees suggest that the battery, automotive parts, and vehicle manufacturing industries in Ontario face significant workforce gaps. The EV battery, parts, and vehicle manufacturing industries commonly face difficulty attracting skilled and diverse talent, an aging workforce, the need for rapid workforce reskilling, and misaligned post-secondary training curricula that are struggling to keep up with rapid changes and developments in the EV manufacturing industry. Interviewees emphasized the tangible impacts of these workforce challenges on employers in the automotive industry. They noted how job vacancies in automotive manufacturing could hinder employers' ability to meet demand for products and services.

Attracting Skilled and Diverse Talent

Discussions with automotive manufacturing experts reveal workforce gaps that could hinder EV manufacturing in the province. A key issue is the recurring shortage of specialized talent with expertise in EV assembly and manufacturing technology. Difficulties attracting skilled manufacturing trades, such as electricians, tools and die makers, and millwrights, also presented a challenge. While Ontario boasts a robust automotive manufacturing workforce, transitioning to EV production requires workers skilled in EV technology, battery assembly, and software integration.

Bridging this skills gap requires targeted training programs and partnerships between educational institutions and industry stakeholders to equip workers with the necessary knowledge and skills. Interviewees also discussed potential solutions for attracting talent from overseas and developing specialized pathways to enhance labour force inflow.

Additionally, interviewees highlighted the challenge of recognizing foreign certificates. Delays and inefficiencies in processing certifications and licences were noted in creating financial strains for would-be apprentices and mid-career skilled immigrants. These challenges are further compounded by the barriers to entry for newcomers with foreign skilled trades experience, limiting the sector's ability to attract diverse talent pools. One automotive expert emphasized the importance of generating interest in EVs within educational institutions and dispelling the notion that automotive work is exclusively blue-collar. This expert noted that attracting more women to pursue careers throughout the automotive industry was also an important step in attracting sufficient talent.

Recent analysis by the FOCAL Initiative finds that within automotive manufacturing in Ontario only 23% of the workforce in vehicle assembly and 25% in parts production are women, despite women accounting for 48% of the total Canadian workforce.[136] Furthermore, FOCAL's analysis found that young women (15-24 years) made up only 6% of workers in vehicle assembly and 7% in parts production.[137]

136 FOCAL Initiative, "Women's Participation in Canada's Automotive Industry," April 2020, https://www.futureautolabourforce.ca/wp-content/uploads/2020/06/Trend-report-Diversity-Women-in-Auto-May27-2020-final.pdf, 5.

137 Ibid., 6.

This is not the only age gap in Ontario's automotive manufacturing workforce. Indeed, significant portions of the workforce—male and female—are aging into retirement, presenting the risk of significant labour shortages in the near future. According to a 2022 OVIN report, the majority of workers in Ontario's automotive and mobility sector fall within the mid-career range of 45 to 64 years old.[138] As these individuals retire over the next decade, there will be a pressing need to fill their positions with new employees. As this is a common story throughout many sectors of the Ontario economy, the automotive industry will need to compete in a fierce talent attraction environment for new workers.

138 Ontario Vehicle Innovation Network, "Talent Strategy & Roadmap for Ontario's Automotive and Mobility Sector," 2022, https://ovin-navigator.ca/wp-content/uploads/2022/01/OVIN_TalentStrategyRoadmap-English-2021.12.17-FINAL-ua.pdf

DIVERSITY CONSIDERATIONS IN ONTARIO'S EV ECOSYSTEM

Equity, diversity, and inclusion (EDI) were highlighted by interviewees and survey respondents as important factors impacting the ability of employers to hire enough talent. While EDI considerations are necessary across the entire EV value chain, data from ICTC's employer survey suggests that EDI is particularly important for automotive manufacturers to consider. Manufacturing respondents were less likely than respondents from the rest of the EV value chain to agree that underrepresented groups are equitably represented in the automotive manufacturing industry.

As seen in Table 9, the most significant discrepancy relates to women. While just 37% of manufacturing respondents felt women are equitably represented in their industry, this was the case for 70% of respondents from the rest of the EV value chain, representing a 33% percentage point gap. The second largest gap occurs for youth aged 18 to 25 (equal to 23 percentage points), followed by people of colour (equal to 22 percentage points), newcomers to Canada (equal to 21 percentage points), and people from Indigenous communities (equal to 19 percentage points). However, it is worth noting that respondents throughout the entire EV value chain reported underrepresentation for most identifiable groups.

Table 9: Perspectives on Equitable Representation in EV Manufacturing and throughout the EV Industry

WHICH GROUPS HAVE EQUITABLE REPRESENTATION?	MANUFACTURING	REST OF EV VALUE CHAIN	DIFFERENCE IN PERCENTAGE
Women	37%	70%	33%
People identifying as gender non-binary or gender non-conforming (GNB/GNC)	10%	20%	10%
People from Indigenous communities	20%	39%	19%
Newcomers to Canada (five years or fewer in Canada)	35%	56%	21%
People from Black communities	24%	35%	11%
LGBTQ2S+	21%	32%	11%
People of colour	30%	52%	22%
People with disabilities	15%	29%	14%
Youth (people 18-25)	25%	48%	23%
None of these communities are equitably represented in our workforce	38%	52%	14%
Don't know/prefer not to answer	6%	33%	27%

Data Source: ICTC EV Industry Workforce Survey. N=150

The Challenge of Rapid Workforce Reskilling

A significant gap identified, according to interviewees, revolves around the rapid pace of technological innovation in the EV industry, demanding continuous reskilling of the workforce across the EV battery and vehicle manufacturing value chain. Interviewees noted that the increasing sophistication of EVs, including their batteries and digital systems, along with changes in type and functionality, poses a challenge for talent engaged in vehicle assembly.

Despite a strong talent foundation in automotive parts manufacturing, significant challenges persist. Moreover, it is projected that most roles in the industry will require skills upgrades, with approximately 50% of workers impacted by new technologies and over 18% by more substantial transformations.[139] This challenge is exacerbated by the rapid pace of technological advancements, which outstrip the training of the existing workforce, necessitating continuous training and upskilling.

139 Ontario Vehicle Innovation Network, "Talent Strategy & Roadmap for Ontario's Automotive and Mobility Sector," 2022, https://ovin-navigator.ca/wp-content/uploads/2022/01/OVIN_TalentStrategyRoadmap-English-2021.12.17-FINAL-ua.pdf

Misaligned Education and Training Curricula

Experts and employers interviewed noted ongoing concern regarding the ability of new graduates to meet industry needs in Ontario. Interviewees stressed that a gap in graduate readiness underscores the necessity to establish WIL opportunities that bridge the divide between industry requirements and post-secondary education programming. Ontario boasts a substantial pool of graduates, with around 63,500 STEM students graduating annually.[140] There is significant competition throughout the Ontario economy for the most driven and skilled graduates with relevant education and training, yet graduates can also struggle to find gainful employment post-graduation.[141]

Within Ontario's post-secondary education system, many of those interviewed noted that a scarcity of equipment available for hands-on experience can act as a barrier to experiential learning and applied skill development. This is a significant problem for EV manufacturing as EV components and equipment slated to be used as training aids in labs and classrooms are still relatively scarce. Education programs fall short in delivering relevant curricula tailored to the specific needed occupations important to the EV value chain, further perpetuating workforce and skills shortages within the industry. Forging a more synergistic alliance between educational institutions and the automotive manufacturing industry stands out as a key remedy for enhancing the EV talent pool.

While expanding training programs is necessary, there is also a substantial opportunity to leverage Ontario's large international student population. Addressing labour force gaps in critical occupations within automotive manufacturing is crucial, requiring targeted recruitment and attraction campaigns. As a recent report by OVIN estimates, 40% of new jobs created between 2015 and 2025 in Canada will be in the skilled trades, yet only 26% of young people aged 13 to 24 are considering a career in these areas.[142] As a few interviewees noted, limited incoming talent is amplified by the fact that young people who select careers in these areas may still face barriers to entry, particularly finding appropriate training and apprenticeship positions. Recruiting and training sufficient numbers of apprentices has been a challenge, which has persisted across Ontario's skilled trades training system for many years.[143]

140 Toronto Business Development Center, "Expansion in Ontario: Which Sectors are Growing the Most," https://www.tbdc.com/expansion-in-ontario-which-sectors-are-growing-the-most/

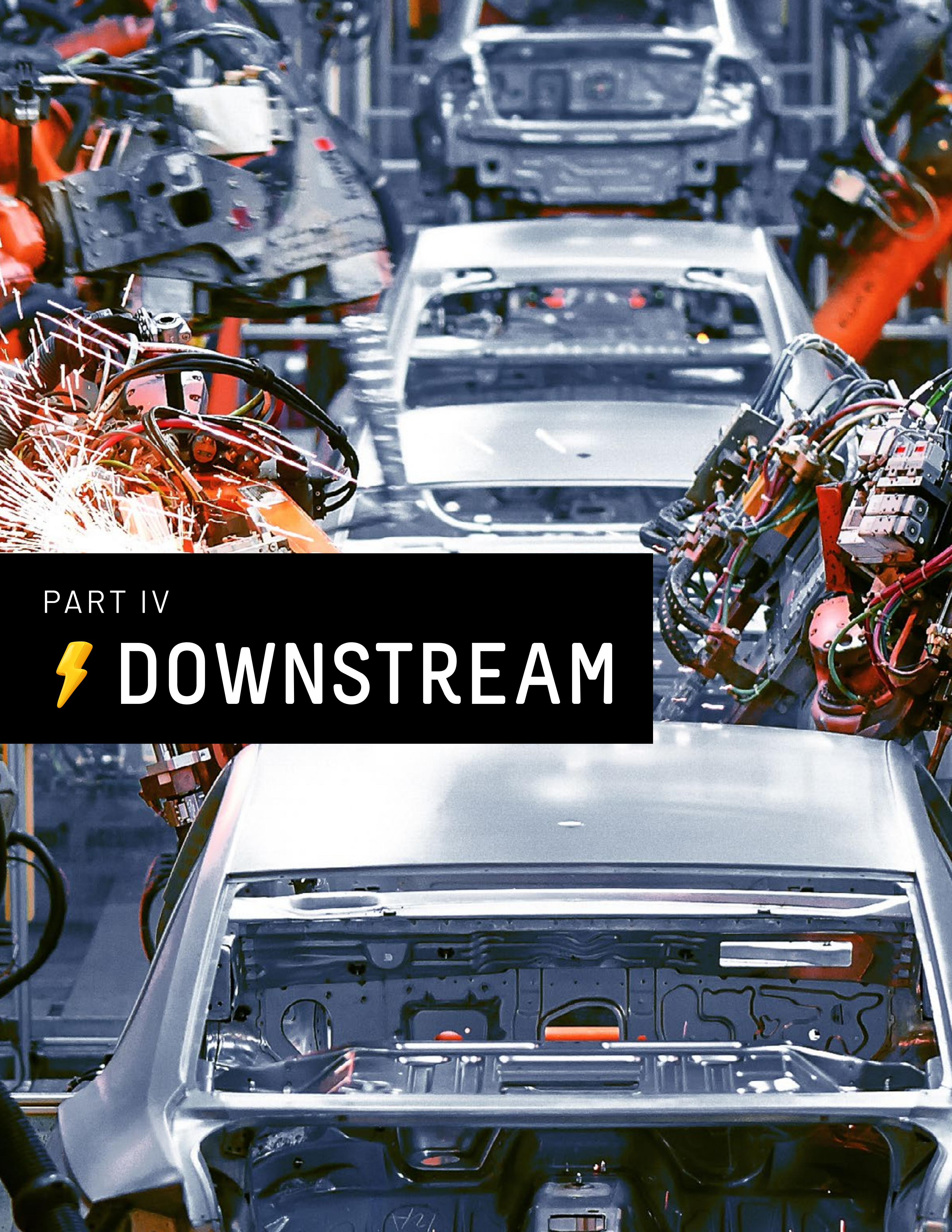
141 Nabeeha Ahmed, "'I need previous work experience to be hired:' Ontario Youth Struggle to Get Their First Job," Youth Research and Evaluation eXchange, York University, November 15, 2023, https://youthrex.com/blog/i-need-previous-work-experience-to-be-hired-ontario-youth-struggle-to-get-their-first-job/

142 "Talent Strategy & Roadmap for Ontario's Automotive and Mobility Sector," OVIN, Dec 2021, https://ovin-navigator.ca/wp-content/uploads/2022/01/OVIN_TalentStrategyRoadmap-English-2021.12.17-FINAL-ua.pdf

143 See: "Demand for skilled trades is soaring. So what's standing in the way of more apprenticeships?" CBC News, March 14, 2023, https://www.cbc.ca/news/canada/skilled-trades-education-1.6773564; David Trick, "Taking Apprenticeship Seriously," Higher Education Quality Council of Ontario, November 20, 2014, https://heqco.ca/david-trick-taking-apprenticeship-seriously/; Erik Henningsmoen, Todd Legere, Heather McGeer, Justin Ratcliffe, "Equitable Recovery and New Frontiers: Understanding Demand and Supply in Manufacturing, Construction, Retail, and Hospitality," 68-71; Human Resources Professionals Association, "Apprenticeship Reform: Ontario's future depends on it," 2014, https://www.hrpa.ca/wp-content/uploads/2020/10/Apprenticeship-Reform-WhitePaper-2014.pdf

PART IV

⚡ DOWNSTREAM



Once an EV is assembled, it can be marketed, distributed, and then sold to a consumer. This sale can happen through a traditional automotive dealership, or directly to the consumer over the internet or through a dedicated EV retail centre, wholly owned by a dedicated EV OEM.[144] From there, EV owners must maintain their vehicles through regular service and maintenance throughout a vehicle's lifecycle. Used EVs may also be sold through used vehicle dealerships.

While EVs do not require gasoline or diesel, like a conventional ICE vehicle, they do require significant electric charging. Drivers can charge their EVs at their homes, places of work or at public charging stations. Public charging stations may be located along a street, co-located at businesses such as parkades, malls, and grocery stores, and at service stations and dedicated EV charging sites. Owners of fleets of EVs may build large-scale dedicated charging infrastructure located at their fleet storage facilities or maintenance yards.

The sales and marketing, service and maintenance, charging of EVs, and the installation of charging infrastructure throughout Ontario, all have workforce implications in terms of new skills and changes to existing occupations. The economic activity generated through these downstream activities are an important component of the EV value chain, with significant economic and job implications.

EV SALES AND MARKETING

EV Sales and Marketing in Ontario

Ontario represents a sizable portion of Canada's new vehicle market, accounting for four out of every 10 vehicle sales in the country.[145] In 2023, over 38,000 EVs were sold in Ontario, making up 5.7% of vehicle sales that year.[146] In most cases, EVs are sold alongside ICE vehicles at dealerships. Each of the major automotive manufacturers now has a line of EVs available in the Canadian market, and finished EVs are integrated into the same distribution system that brings finished ICE vehicles from the factory to dealerships across the country.

In Ontario, there are approximately 8,200 auto dealerships that employ over 30,000 salespeople.[147] A 2020 report by PwC indicates that Ontario dealerships provide an estimated 57,000 direct jobs and generate $48 billion in retail sales annually.[148] Alongside traditional dealership sales, there have also been developments in online car sales that allow customers to shop for vehicles and arrange financing through dealers or allow direct purchasing and delivery.[149] There are also online vehicle-buying platforms operating in the Canadian market, which include CarDoor, Vinn Auto, and Car Monk.[150]

144 See: Business Wars, "Tesla vs Detroit: Motor City Fights Back (podcast)," 2022, https://www.imdb.com/title/tt19853144/

145 "2022 auto sales worst since 2009, but December numbers offer hope," Automotive News Canada, January 4, 2023, https://canada.autonews.com/retail/2022-canadian-auto-sales-plunge

146 Statistics Canada (Government of Canada), "New motor vehicle registrations: Quarterly data visualization tool," last update March 12, 2024, https://www150.statcan.gc.ca/n1/pub/71-607-x/71-607-x2021019-eng.htm

147 "About OMVIC - Ontario's Vehicle Sales Regulator," Ontario Motor Vehicle Industry Council, accessed May 2023, https://www.omvic.on.ca/portal/AboutOMVIC.aspx

148 PwC, "The Economic footprint of automobile dealerships in Ontario," Trillium Automobile Dealers Association, January 2020, https://tada.ca/wp-content/uploads/2020/02/TADA-PWC-Economic-Study.pdf

149 "Canadian car buyers flock to online shopping tools," Automotive News Canada, May 14 2018, https://canada.autonews.com/article/20180514/CANADA/180519882/canadian-car-buyers-flock-to-online-shopping-tools

150 Carmen Chai & Chelsey Hurst, "5 companies like Carvana in Canada," Finder CA, last update: November 24, 2023, https://www.finder.com/ca/companies-like-carvana-canada

In the US, there are laws in many states that mandate the use of dealerships for automotive sales and distribution. This has been identified as a challenge for newer EV companies like Tesla that use an alternative direct-to-consumer sales model.[151] Notably, Canada does not have laws against automotive companies opening their own retail stores, as seen with Tesla and Mercedez Benz factory stores throughout the country.[152] EV companies like Lucid, Rivian, and Polestar have also used a similar strategy to bypass dealerships and sell directly to customers—in some instances, delivering new EVs directly to buyers' homes.[153] However, the physical presence of these dedicated EV companies is much more limited than that of traditional automotive manufacturers and their affiliated dealership networks. The franchise retail dealership distribution model, where manufacturers focus on designing, building, and marketing their vehicles and the dealers invest in local marketing, sales, and service experiences, has largely remained in place despite these new industry developments.[154]

The Role of Dealerships and Automotive Sales Centres

One of the perennial challenges in EV adoption is raising awareness and informing customers of the capabilities of the current technology. One online study of 700 Canadians found that "online video, third-party review websites, and manufacturer websites are the top information sources potential buyers use to learn more about EVs, with dealerships down the list and tied with friends and family as the preferred EV information source for 27% of respondents."[155] This may indicate many purchases are driven by enthusiasm for EVs, personal research, and word-of-mouth.

According to Google and Autosyc's 2023 *Google Think Auto Report*, when consumers are shopping for new vehicles, 89% of consumer research takes place online.[156] The report also finds that two-thirds of those interested in purchasing EVs "said they plan to make their next purchase completely online."[157] Furthermore, 12% of EV owners had made a vehicle purchase online in the past, showing how EV consumers are more comfortable purchasing new vehicles online and using online information to make purchasing decisions.

In North America, only 11% of new vehicles are purchased online, while 76% of North American car buyers "discovered" the vehicle online that they eventually purchased.[158] Furthermore, just over 60% of North American consumers report being open to purchasing a vehicle online.[159] North American consumers only visited an average of 1.9 dealerships before purchasing a new vehicle—the lowest average dealership visit rate in the world—and, on average, took 1.7 test drives before making a new vehicle purchase.[160]

151 "Are Auto-Dealership Protection Laws Holding Back Electric Vehicle Adoption?" Clean Technica, January 30, 2022, https://cleantechnica.com/2022/01/30/are-auto-dealership-protection-laws-holding-back-electric-vehicle-adoption/

152 Jason Tchir, "Why can't we buy cars directly from car companies?" Globe and Mail, Feb 18, 2014, https://www.theglobeandmail.com/globe-drive/culture/commuting/why-cant-we-buy-cars-directly-from-car-companies/article16935030/

153 Tim Levin, "Electric-car startup Polestar bets you'd rather buy a car from your couch than go to a dealership," Business Insider, June 22, 2022, https://www.businessinsider.com/polestar-electric-ggpi-stock-tesla-ev-car-buying-2022-6

154 See: "Auto Retailing: Why the Franchise System Works Best," National Automobile Dealers Association," accessed March 12, 2024, https://www.nada.org/media/3264/download?inline https://www.nada.org/media/3264/download?inline

155 "Consumer Research Results: How Canadian Consumers Feel About Electric Vehicles," Trader, May 25, 2021, https://go.trader.ca/consumer-research-results-how-canadian-consumers-feel-about-electric-vehicles/

156 AutoSync & Google, "Google Think Auto 2023," March 2, 2023, https://www.autosync.ca/wp-content/uploads/2023/03/Google-Think-2023-Presentation-Slides.pdf, 31.

157 Ibid., 41.

158 Google, "Gearshift 2021: New Car Buyers Global Report," August 2021, https://drive.google.com/file/d/1OXlEuCJn2CuXpGdVMOUSitHJLBpH198C/view, 19.

159 Ibid., 22.

160 Ibid., 20.

These data on North American consumer vehicle purchasing habits suggest that digital marketers and e-commerce specialists can play a significant role in the automotive dealerships and EV sales centres in Ontario. While it is tempting to speculate that, in the near future, Canadian consumers will begin purchasing new vehicles solely online, the data indicates that, while many consumers prefer to do research online, some consumers may also rely on physical dealerships to test drive vehicles and benefit from face-to-face interactions with salespeople to make their final purchasing decisions. The data also highlights the opportunity for dealerships to seamlessly integrate their digital marketing and e-commerce capabilities with their physical salesforce to create a seamless EV purchase experience.[161]

EV MAINTENANCE AND REPAIR

Overview of EV Maintenance and Repair

While there are reduced maintenance costs for EVs when compared to ICE vehicles, based on EVs' lower number of moving parts, there are still ongoing maintenance needs such as tire rotation (due to heavier vehicles), brake fluid service, battery coolant service, brakes, and batteries (mitigating issues of cycling, extreme temperatures etc.).[162] Due to the complex nature of EVs and the inherent dangers of high-voltage systems, repairs and maintenance should be done with caution and making use of knowledgeable service providers.[163]

Theoretically, any EV model should be repairable at any automotive service garage that works on EVs—however, some shops may only repair specific EV brands or models.[164] Increased computerization of these vehicles also leads to increased challenges for servicing with a need for specialized technicians.[165] Interestingly, Tesla has stated that most service issues can be addressed on the spot using vehicle diagnostics and mobile repair technicians rather than needing to bring the vehicle to a servicing facility.[166] In other cases, new developments, such as mobile battery repair services, are coming to market.[167]

The ability to perform repairs on EVs at independent automotive repair garages outside of the dealership networks is difficult to specify. These shops may not have access to OEM specialized training. Furthermore, even dealerships may lack qualified technicians to service the EVs they sell.[168] One of the most significant issues in repairing EVs is the difficulty in diagnosing problems—whether due to locked-down data or a lack of training and specialized equipment to perform EV diagnostics.[169]

161 Also, see: Deloitte, "Disruption in the automotive industry: How digital in changing car sales," 2019, https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/consumer-business/deloitte-uk-digital-changing-car-sales.pdf

162 Jack Fitzgerald, "Electric Car Maintenance: Everything You Need to Know," Car and Driver, Oct 16, 2022, https://www.caranddriver.com/shopping-advice/a40957766/electric-car-maintenance/

163 "Electric and Hybrid Vehicle Risks," EINTAC, accessed July 2023, https://eintac.com/risks-working-electric-hybrid-vehicles/

164 Nick Versaw, "Electric Car Repair: Common Problems and How to Fix Them," Compare, Jan 6, 2022, https://www.compare.com/other-products/vehicle/electric-cars/guides/electric-car-repair

165 "Do Electric Vehicles Change Everything in Auto Repair?" AutoTechIQ, December 27, 2022, https://www.nasdaq.com/press-release/do-electric-vehicles-change-everything-in-auto-repair-2022-12-27

166 See: "Service," Tesla, accessed March 16, 2024, https://www.tesla.com/service

167 Thomas Rudy, "A New Era of Auto Repair: How Electric Cars Will Be Fixed in the Future and What It Means for Consumers," Yahoo! Finance, February 16, 2023, https://finance.yahoo.com/news/era-auto-repair-electric-cars-150556176.html

168 Dale Molnar, "Why electric vehicle owners are pushing to drive change in how mechanics are trained," CBC News, October 4, 2021, https://www.cbc.ca/news/canada/windsor/electric-vehicles-mechanics-windsor-college-1.6196274

169 Scott Marshall, "Electric vehicle repair: what are your options?" Rates.ca, September 15, 2022, https://rates.ca/resources/options-for-electric-vehicle-repair

Independent garages interviewed for this study mentioned the pains taken to interpret locked-down maintenance codes for some models of EVs. These garages also reported struggling to obtain repair manuals and specialized parts of EVs in some cases. Service technicians working for OEM-affiliated dealerships tend to face fewer of these challenges as they have significantly better access to OEM training, diagnostic and repair information, manuals, specialized tools, and parts.

Dealerships and independent automotive repair shops require investments and training to provide specialized EV maintenance and repair services, such as onsite charging infrastructure, work bays equipped with special lifts for heavier EVs, lifting equipment for removing large, heavy batteries, and specialized tools to repair EV battery cooling systems. Furthermore, there are increased safety protocols required when working with EVs and specific personal protective equipment (PPE) for technicians. Shop facilities may need to be upgraded with high-voltage bays or repair rooms with higher ceilings and ventilation systems in case of battery fires or even external battery bunkers for safe and secure EV battery storage.[170]

170 Laurance Yap, "What Dealers are Doing to Service EVs," Green Cars, May 2022, https://www.greencars.com/news/what-dealers-are-doing-to-service-evs

EV MAINTENANCE AND RIGHT TO REPAIR

One pertinent issue that was commonly discussed by interviewees running independent garages and used car dealerships was the "right to repair"—or the legal right for consumers to repair items themselves or through independent repair shops rather than going through an OEM or authorized repairer.[171] This is an especially pertinent issue for automotive service technicians tasked with working on increasingly computerized and locked-down vehicles. Independent garages lament that they have constant challenges accessing documentation, training, and diagnostic capabilities to service EVs efficiently. However, there are also arguments that tight control of EV systems is necessary due to the highly integrated and complex nature of components as well as the inherent safety risks of high-voltage systems.

171 Natasha Tusikov, "Giving Canadians the Right to Repair Empowers Consumers, Supports Competition and Benefits the Environment," The Conversation, April 9, 2023, https://theconversation.com/giving-canadians-the-right-to-repair-empowers-consumers-supports-competition-and-benefits-the-environment-203302

EV CHARGING INFRASTRUCTURE

Overview of EV Charging Infrastructure

Charging infrastructure is commonly broken down between Level 1, Level 2, and Level 3 (i.e., "DC Fast-Charging") charging stations.[172] Level 1 charging consists of a small, normally portable charger that can be plugged into a standard electrical outlet and then connected to an EV charging port. Level 1 charging is significantly slower than larger, more powerful chargers but requires no comprehensive charging infrastructure. Conversely, Level 2 and Level 3 charging require dedicated and comprehensive charging infrastructure, with Level 3 being more common at dedicated EV charging sites. Level 2 and Level 3 charging stations require significant electrical work to install. Dedicated charging infrastructure also requires ongoing service and maintenance to keep charging stations operational.[173]

A 2022 study of Canadian views of EV charging infrastructure found that "the existence of multiple public charging networks operated by a variety of different entities, as well as the uneven distribution of charging infrastructure, has greatly impacted the public charging experiences of EV users."[174] Regarding the adequacy of EV charging infrastructure in Canada, 52% of respondents reported that access to charging stations was a major consideration when purchasing an EV.[175] Furthermore, 59% of respondents reported that charging infrastructure was inadequate, and 22% reported that charging station amenities were inadequate.[176]

The theme of ready access to EV charging as a major purchasing decision is apparent in that 85% of Canadian EV owners reside in single-family dwellings, while just 12% reside in multi-unit dwellings.[177] Users who reside in multi-unit dwellings rely on public charging stations significantly more when compared to EV owners living in single-family dwellings, with 42% of users relying on public charging stations for more than half of their EV charging needs.[178] This is significant, as record high housing prices in Ontario, coupled with limited land availability in major population centres, such as the GTA, have necessitated that more and more of Ontario's new housing stock consists of multi-unit dwellings.[179]

It's clear that solving the EV charging infrastructure puzzle in Ontario will be an important factor in encouraging more drivers to consider EVs for their next vehicle purchase. The build-out, operations, and maintenance of charging infrastructure require significant labour by skilled workers such as electricians.

172 SAE International, "Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology," (SAE J2954), November 2020, https://www.sae.org/standards/content/j2954_202010/

173 U.S. Department of Energy, "Operation and Maintenance for Electric Vehicle Charging Infrastructure," accessed February 13, 2024, https://afdc.energy.gov/fuels/electricity_infrastructure_maintenance_and_operation.html

174 Pollution Probe, Assessment of The Consumer Electric Vehicle Charging Experience in Canada: Final Project Report, April 2022, https://www.pollutionprobe.org/wp-content/uploads/2022/06/Pollution-Probe-.Consumer-EV-charging-Experience.pdf, 3.

175 Ibid., 12

176 Ibid., 12-16.

177 Ibid., 10.

178 Ibid., 11.

179 REMI Network, "Multi-unit projects drive 2022 housing starts," January 19, 2023, https://www.reminetwork.com/articles/multi-unit-construction-drives-housing-starts-in-2022/

EV Charging Infrastructure in Ontario

Having ready access to charging stations is an important consideration for EV drivers. According to the Ontario government, as of October 2023, there were over 2,900 public charging stations throughout the province, with a total of 8,000 individual charging ports.[180] While charging infrastructure in Ontario continues to be expanded, with more and more charging stations coming online, there are concerns that rural communities, such as those in Northern Ontario, are lacking appropriate charging infrastructure.[181] In October 2023, the Ontario government announced $91 million in charging infrastructure funding for small and medium-sized communities through its EV ChargeOn program to help address this charging infrastructure gap.[182] The province has also made recent attempts to streamline the process for local utilities to connect public charging infrastructure to the electricity grid.[183]

Installing public charging networks represents a significant investment, as installing one Level 2 charging station can cost upwards of $2,000 to $10,000, whereas one Level 3 charging station can cost $50,000 to $100,000 or more, according to an analysis by CSA Group.[184] An assessment commissioned by Natural Resources Canada concluded that $20 billion in investment in public charging infrastructure will be required over the next three decades to build out an appropriately sized EV charging network throughout the country.[185] As Canada's most populous province, Ontario will require a significant share of this investment. Building out such a charging network represents a significant and long-term work opportunity for electrical contractors and skilled tradespeople, such as residential, maintenance, and industrial electricians.

Building Out Ontario's Private Home Charging Infrastructure

In addition to public charging infrastructure, a second key component of Ontario's EV charging landscape is private home-based charging. While Level 1 chargers can easily be used with most residential power outlets, such chargers can be extremely slow, with adequate charging needed even for short commuting distances that take several hours. Drivers who rely on their EVs for day-to-day use may opt to invest in a dedicated Level 2 charger in their home for personal use. Yet, this can be complicated by the nature of housing and home ownership in contemporary Ontario.

A 2023 survey of EV drivers commissioned by the Canadian Automobile Association (CAA) found that Canadians living in single-family dwellings and who owned their homes were significantly more likely to own an EV when compared to renters and those living in multi-unit dwellings.[186] Furthermore, for Canadians living in multi-unit dwellings, such as condos and apartments, access to home charging proved to be a challenge, with 22% of EV drivers living in multi-unit dwellings having no access to home charging, according to the CAA survey.[187]

180 Government of Ontario, "Charging electric vehicles," last update October 25, 2023, https://www.ontario.ca/page/charging-electric-vehicles

181 "EV charging infrastructure program failed to prioritize underserved areas, says report," CBC News, November 8, 2023, https://www.cbc.ca/news/canada/sudbury/ev-charging-gap-1.7021356

182 "Ontario invests $91M to add EV charging stations in smaller communities," Global News, October 20, 2023, https://globalnews.ca/news/10038336/ontario-funding-ev-charging-stations-smaller-communities/

183 Government of Ontario, "Ontario Making it Easier to Build Electric Vehicle Charging Stations (Press Release)," February 16, 2024, https://news.ontario.ca/en/release/1004197/ontario-making-it-easier-to-build-electric-vehicle-charging-stations

184 Jordann Thirgood, "Charging Ahead: Ensuring Equity and Reliability in Canada's Electric Vehicle Network," CSA Public Policy Centre, December 2022, https://www.csagroup.org/article/public-policy/ensuring-equity-accessibility-and-reliability-across-canadas-electric-vehicle-charging-network/, 9.

185 Dunsky Energy + Climate Advisors, "Canada's Public Charging Infrastructure Needs – Updated Projections," Natural Resources Canada, March 2022, https://natural-resources.canada.ca/energy-efficiency/transportation-alternative-fuels/resource-library/updated-projections-canadas-public-charging-infrastructure-needs/24504, 24.

186 PlugShare Research, "The Voice of the Canadian Electric Vehicle Driver," Canadian Automobile Association, 2023, https://www.caa.ca/app/uploads/2023/04/CAA-Canadian-EV-Driver-Study-2023.pdf, 18.

187 Ibid., 19

According to the 2021 census, single detached houses made up 53.6% of Ontario's housing stock, with the rest consisting of apartments, condos, and other multi-unit dwellings. In Toronto, single detached houses make up only 39% of the city's housing stock.[188] Yet, getting home EV charging infrastructure into multi-unit dwellings remains a challenge in Ontario.

According to Google's 2021 *Gearshift* global automotive buyer behaviour study, 62% of North American consumers cited a lack of charging stations and limited EV range as significant barriers to purchasing an EV. While consumer surveys report a high degree of interest in EVs from North American consumers, the Gearshift study found that only one-third of those interested in purchasing an EV end up doing so.[190]

Multi-unit housing often does not have access to a driveway or garage in which to place EV charging infrastructure, and furthermore, few high-rise buildings in Ontario have the infrastructure in place to readily install charging equipment.[191] Installing charging infrastructure in existing high-rise buildings can be costly. A 2023 report by the Pembina Institute notes, "Installing chargers often entails extensive renovations to connect to electrical infrastructure and can be costly and complex; projects frequently require approval from multiple stakeholders."[192] In 2018, the Condominium Authority of Ontario published a best practice guide and framework for condo boards to install charging stations in Ontario condominiums.[193]

Like the build-out of public charging infrastructure, installing charging stations in people's homes and in multi-unit dwellings promises to be a significant, complicated, long-term project and, thus, a substantial opportunity for electrical contractors and the skilled tradespeople they employ, such as residential and maintenance electricians.

DOWNSTREAM LABOUR SUPPLY AND DEMAND

Downstream labour demand is going to be related to the functions described above. Namely, it involves marketing, selling, and servicing the EV as well as building the infrastructure that is needed to ensure a sufficient supply of charging. Across these pillars, there are different types of jobs that are in demand, each relating to one or more of the core functions discussed above: sales and administrative functions, individuals with the skills and competencies to repair and service EVs, and individuals in the trades to build out and service the network of chargers, both public and private.

188 Statistics Canada, "Focus on Geography Series, 2021 Census of Population," last update December 16, 2022, https://www12.statcan.gc.ca/census-recensement/2021/as-sa/fogs-spg/page.cfm?lang=E&topic=3&dguid=2021A000011124#

189 Google, "Gearshift 2021: New Car Buyers Global Report," August 2021, https://drive.google.com/file/d/1OXIEuCJn2CuXpGdVMOUSitHJLBpH198C/view, 27.

190 Ibid., 25.

191 KPMG, "The road to adoption: building EV infrastructure and smart grids," June 2022, https://kpmg.com/ca/en/home/insights/2022/06/the-road-to-adoption-building-ev-infrastructure.html

192 Steven Han & Jason Wang, "A Guide to Installing EV Infrastructure in Alberta's Multi-Unit Residential Buildings," Pembina Institute, July 2023, https://www.pembina.org/pub/guide-installing-ev-infrastructure-albertas-multi-unit-residential-buildings, 1.

193 Condominium Authority of Ontario, "Best Practices Guide: Installing Electric Vehicle Chargers," 2023, https://www.condoauthorityontario.ca/resource/electric-vehicle-charging-systems/

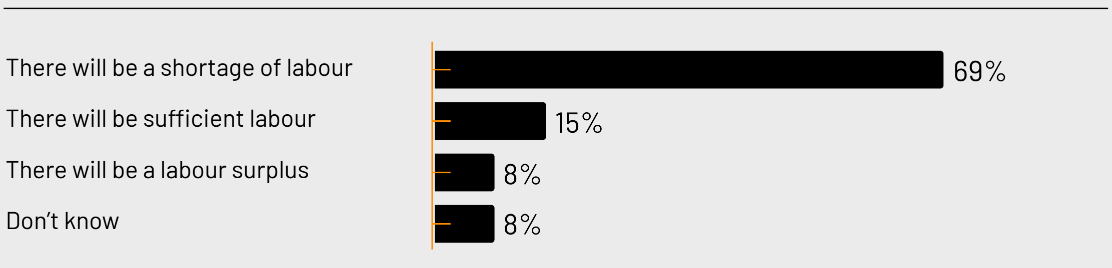
Demand for these roles is fundamentally dependent on consumer demand for EVs. Sales will be tied to the portion of the public that believes EVs are a viable alternative to ICEs. Similarly, demand for roles to support charging infrastructure and maintenance will depend on the number of EVs sold and driven in Ontario over the long term. However, with the rollout of the federal government's Electric Vehicle Availability Standard, EVs can be expected to make up a greater and greater proportion of Ontario's light-duty vehicle fleet over time.

Given that EVs are still emerging as a common vehicle type, it is difficult to get a good baseline of how much demand there will be for EV-related roles in Ontario. Currently, maintenance of EVs is typically handled by the OEM or dealerships, with some focus on third-party independent service garages. This is not to say that there will not be changes in the future, but only that, as of now, this is how the system has emerged. In Ontario, there are already challenges with the supply of qualified individuals with automotive maintenance skills, even for ICEs. Currently, automotive dealerships and service garages are having trouble retaining service technicians in Ontario and, in many cases, are relying on temporary foreign workers.[194] A report commissioned by the Motor Vehicle Retailers of Ontario documents how the automotive workforce is aging, and there are fewer individuals pursuing apprenticeships in this field.[195]

As discussed above, outside of the fully electric lines such as those produced by Tesla, Rivian, and Polestar, EVs tend to be sold alongside traditional ICE and hybrid vehicles. This means that the EV salesforce co-exists alongside the ICE salesforce. Indeed, most dealerships interviewed for this report indicated that their automotive salespeople cover both ICE and EVs and are expected to be able to sell both—though dealerships that place a heavy emphasis on EVs may have sales specialists dedicated to EV sales as part of their teams. Ontario automotive sales employees, such as those who work at dealerships, surveyed for this report expect that there will be a shortage of automotive sales labour in the province.

Figure 11: Automotive Sales: Will There Be a Sufficient Supply of Labour?

SALES: WILL THERE BE A SUFFICIENT SUPPLY OF LABOUR?



Data Source: ICTC EV Industry Workforce Survey. (N=13)

194 MNP, "The Labour Market for the Automotive Trades in Ontario and the Impact on New Car and Truck Retailers," Motor Vehicle Retailers of Ontario, August 2023, https://files.constantcontact.com/14115e3d101/1edb496a-9d3f-479b-bd43-2e2b27969e5f.pdf?rdr=true, 3.

195 Ibid.

In addition to conducting a survey, ICTC used insight from its primary and secondary research to map Statistics Canada's National Occupational Classifications (NOC) codes to known occupations in the downstream segment of the EV value chain (see Table 10).[196] This enabled ICTC to use Statistics Canada's Labour Force Survey to track employment in relevant downstream occupations in Ontario over time, as well as the unemployment rate for Ontario's downstream labour force.

Table 10: NOC Codes and Job Titles Pertaining to the Downstream Component of the EV Value Chain

NOC CODES	
20011	Architecture and science managers
21109	Other professional occupations in physical sciences
21202	Urban and land use planners
21221	Business systems specialists
21300	Civil engineers
22310	Electrical and electronics engineering technologists and technicians
64100	Retail salespersons and visual merchandizers
64409	Other customer and information services representatives
72011	Contractors and supervisors, electrical trades and telecommunications occupations
72100	Machinists and machining and tooling inspectors
72200	Electricians (except industrial and power system)
72201	Industrial electricians
72203	Electrical power line and cable workers
72400	Construction millwrights and industrial mechanics
72410	Automotive service technicians, truck and bus mechanics and mechanical repairers
72422	Electrical mechanics
90011	Utilities managers
94200	Motor vehicle assemblers, inspectors and testers
94201	Electronics assemblers, fabricators, inspectors and testers
94202	Assemblers and inspectors, electrical appliance, apparatus and equipment manufacturing
94203	Assemblers, fabricators and inspectors, industrial electrical motors and transformers
94204	Mechanical assemblers and inspectors

JOB TITLES
Administrative Assistant
Automotive Advisor
Automotive Mechanic
Automotive Sales Assistant
Automotive Sales Consultant
Automotive Sales Manager
Automotive Sales Professional
Automotive service advisor
Automotive Service Manager
Automotive Service Technician
Automotive Parts Specialist
Automotive Technician
Customer Sales Representative
Electrician
Front Desk Receptionist
Industrial Electrician
Lot Attendant
Maintenance Electrician
Mechanic
Operations Manager
Parts Advisor
Porter
Receptionist
Residential Electrician
Sales Associate
Sales Manager
Sales Representative
Service Assistant
Service Porter
Service Technician

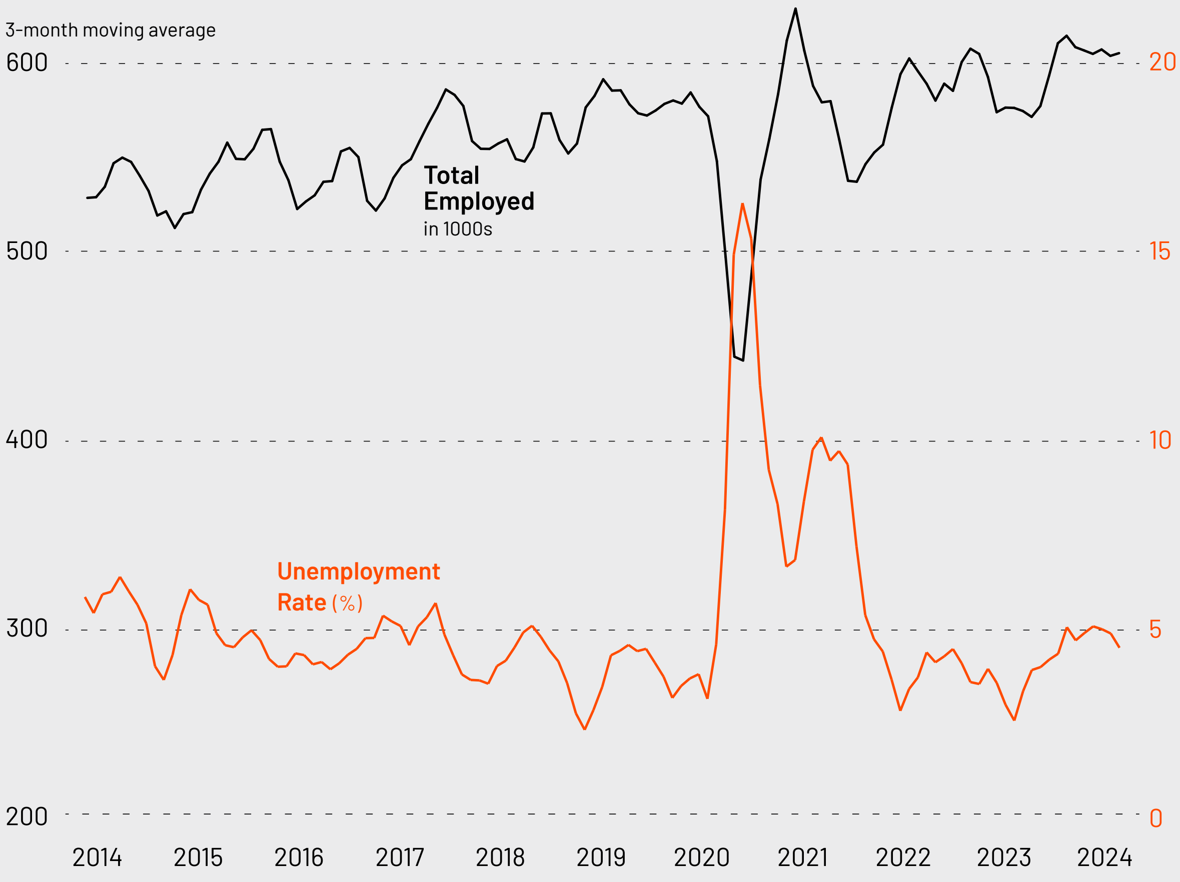
Data source: NOC Codes identified using Statistics Canada, ICTC analysis. Job titles identified using publicly available data, ICTC analysis.

196 See: Javier Colato & Lindsey Ice, "Charging into the future: the transition to electric vehicles," US Bureau of Labour Statistics, Beyond the Numbers, vol. 12, no. 4, February 2023; James Hamilton, "Careers in Electric Vehicles," US Bureau of Labor Statistics, September 2011, 5-12; Shannon M. Sedgwick & Christine Cooper, "Electric Vehicles: The Market and Its Future Workforce Needs," Los Angeles County Economic Development Corporation, August 2012 , 33; "Electric Vehicle-Battery Value Chain Talent Requirements," Invest Windsor/Essex, December 2021.

Currently, there are many Ontario residents working in occupations relevant to downstream EV employers. High employment is driven, in part, by the number of individuals working in sales-related occupations. Two occupations, "retail salespersons and visual merchandizers" and "other customer and information services representatives," account for approximately 50% of Ontarians employed in downstream-related occupations.[197] Unfortunately, it is not possible to disaggregate NOC codes further to distinguish between those working in automotive sales versus retail and professional sales occupations in other sectors of Ontario's economy.

Many of the downstream occupations are in-person roles, impossible to carry out as remote work. This is evident in the substantial drop in employment and the adjacent rise in the unemployment rate between 2020 and 2021 during the early days of the pandemic. Employment in these occupations has grown substantially since the pandemic, while the unemployment rate has hovered approximately between 2.5% and 6%, suggesting that there remains high demand and high levels of hiring in these roles.

Figure 12: Ontario Residents Engaged in Downstream Occupations Relevant to the EV Value Chain



Data Source: Statistics Canada Labour Force Survey, ICTC Analysis.

196 See: Javier Colato & Lindsey Ice, "Charging into the future: the transition to electric vehicles," US Bureau of Labour Statistics, Beyond the Numbers, vol. 12, no. 4, February 2023; James Hamilton, "Careers in Electric Vehicles," US Bureau of Labor Statistics, September 2011, 5-12; Shannon M. Sedgwick & Christine Cooper, "Electric Vehicles: The Market and Its Future Workforce Needs," Los Angeles County Economic Development Corporation, August 2012 , 33; "Electric Vehicle-Battery Value Chain Talent Requirements," Invest Windsor/Essex, December 2021.

EV Sales and Marketing: Workforce Gaps

For Ontario's automotive salesforce and marketers, there were no significant structural workforce gaps identified, though as discussed above, there is expected to be a significant shortage of labour. Hiring skilled automotive salespeople—who can sell vehicle inventory and thus keep the dealership profitable—is a perennial challenge for dealerships. A white paper by Cox Automotive estimates that staff turnover at US automotive dealerships averages 40% annually but can be as high as 67% for sales positions.[198]

Dealerships and automotive salespeople interviewed noted that successfully selling EVs requires salespeople to develop their product knowledge of EVs and understand and foresee common concerns customers have when purchasing EVs to be successful in selling this novel automotive product. Furthermore, the rise of EVs in Ontario dealerships comes at a time when digital marketing and e-commerce activities are becoming increasingly common at dealerships across Canada. Automotive salespeople will need to learn to work alongside their digital marketing and e-commerce colleagues—as well as technical specialists such as app developers—in an automotive sales environment that increasingly straddles the line between physical and digital environments.

During interviews with dealerships and individual automotive salespeople, interviewees emphasized how similar selling EVs was to selling ICE vehicles. While there are significant differences between EVs and ICEs, automotive salespeople in Ontario should be prepared to sell both. One dealership, which has placed a significant focus on EV sales as part of its growth strategy, noted, "Our philosophy has not been to create dedicated EV sales teams." Instead, this employer provides its sales team with training and product knowledge to sell both ICE vehicles and EVs.

Another salesperson who specializes in EV sales for their respective dealership reflected that while there are nuances to EVs, core automotive sales skills remain the same. To become great at selling EVs requires salespeople to learn the specifics of EV products, be able to assuage customer concerns—such as range anxiety—and be able to authoritatively discuss issues such as federal EV purchase incentives. But core sales skills such as empathy, enthusiasm for the product, and interpersonal communications remain the same. From a hardware perspective, dealerships need to have EV chargers installed to ensure EVs are adequately charged for customer test drives and to demonstrate to customers how charging stations work in practice.

A number of automotive salespeople interviewed for this study noted that as many EV consumers are "early adopters" of emerging technology, they tend to be interested in a more technical conversation about things like vehicle specifications with sales staff. For this reason, extensive product knowledge can be critical to being a successful EV salesperson.

Furthermore, salespeople observed that while some customers view EVs as an environmentally conscious or ethical purchase, others are more driven by financial considerations, such as fuel cost. It is important that automotive salespeople understand how to segment different customer needs and speak to the issues individual customers place the most emphasis on.

198 Cox Automotive, "Dealership Staffing Study: Meeting the Challenges of a Changing Workforce," 2017, https://www.coxautoinc.com/wp-content/uploads/2017/09/302433_Dealership-Staffing-Study-Brochure-DIGITAL.pdf, 4.

One EV sales specialist interviewed also shared they will only show customers EVs if prompted to, as this salesperson found that customers will enter a dealership intending to either purchase an EV or an ICE vehicle—few customers will step onto a dealership sales floor indifferent about the type of vehicle they are interested in purchasing.

Completing the Ontario Motor Vehicle Industry Council (OMVIC) Automotive Certification Course is an obligatory requirement to become an automotive salesperson in Ontario.[199] When asked if there was a need for further EV sales certification, none of the interviewees thought that was necessary as the core competencies provided by the current Automotive Certification Course remain the same for EVs. This being said, a number of interviewees expressed some appetite for specific EV sales training from third-party sources. Dealerships affiliated with an OEM are normally provided with product training by the OEM. Such training can last several days or just a few hours, depending on the OEM providing the training. However, used car dealerships with no direct OEM affiliation must develop their own in-house EV product training or expect their sales teams to self-educate.

Some used car dealerships reported difficulty in assessing the state of used EV batteries when purchasing used EV inventory and pricing used EVs for resale, with some seeing this issue as a major business risk, as the battery is such a significant portion of the EV's total value. This has reportedly made some used vehicle dealerships in Ontario reluctant to develop significant EV sales channels. However, specialized used EV dealerships interviewed for this research did not view assessing the state of used EV batteries as a major business challenge. This insight suggests that accurately assessing the condition of used EV batteries will be a core skill and a potential source of competitive advantage in the used EV sales market going into the future.

In the face of a step change in the amount of digital marketing and e-commerce taking place throughout the automotive sales industry, OEM-affiliated dealers and independent used vehicle dealerships have an opportunity to align their physical salesforce with their digital marketing and e-commerce team. Rather than being thought of as two distinct approaches to automotive sales, there is an important linkage between digital marketing and physical automotive sales. A challenge for dealerships and sales managers is developing strategies to effectively connect these two sales and marketing domains.

EV Maintenance and Repair: Workforce Gaps

A common observation amongst those interviewed from the automotive service industry was the considerable shortage of automotive service technicians (or mechanics) working in dealerships and independent garages across Ontario. A 2023 study by consultancy MNP estimates that there are over 3,000 job vacancies for automotive service technicians in the province, a number that has doubled since the pandemic.[200] This presents a workforce challenge for Ontario's downstream consumer EV industry, as scarce automotive service technicians are currently needed to repair and maintain both EVs and ICE vehicles in the province.

199 "OMVIC," Georgian College, accessed March 14, 2024, https://www.georgiancollege.ca/omvic/

200 MNP, "The Labour Market for the Automotive Trades in Ontario and the Impact on New Car and Truck Retailers," Motor Vehicle Retailers of Ontario, August 2023, 3.

While some EV OEMs have centralized service and maintenance depots to repair customer vehicles, most EVs driving on Ontario roads will receive the majority of their lifecycles service and maintenance needs through dealerships and independent automotive service garages. While there are specialized automotive businesses in Ontario that focus on servicing EVs, most garages servicing EVs also service ICE vehicles. In fact, most service garages presently do most of their business servicing ICE vehicles, with EVs accounting for only small portion of the overall business. As one garage owner interviewed for this study noted, that for every "100 vehicles that come in, there's one EV that comes in for service." While EVs are becoming more common on Ontario roads every day, they are still relatively uncommon.

In all but the most specialized Ontario garages, automotive service technicians will need to be able to work on both ICEs and EVs. This requirement will ask automotive service technicians to improve their technical knowledge of EV repair while still maintaining their core competencies in maintaining conventional ICEs. Developing the competencies in EV repair requires automotive service employers to invest time and financial resources in upskilling their automotive service technicians on EV technology. While interviewees from the automotive service sector reported having difficulty accessing EV maintenance training for their employees, there are a number of new initiatives that can fill this training and workforce development gap.

The Automotive Aftermarket Retailers of Ontario provides a three-day training program with a certificate of completion for existing automotive technicians to work on hybrids and EVs, including interpreting diagnostic data and working with high-voltage systems.[201] The Automotive Industries Association of Canada and St. Lawrence College provide no-cost training to upskill currently unemployed and underemployed industry workers for maintenance and repairs on EVs with eight full-day modules.[202] St Clair College has also launched Ontario's first EV technician diploma program, which was designed in consultation with manufacturers like Ford, Tesla, Stellantis and Rivian.[203] The National Automotive Parts Association (NAPA) offers an EV and hybrid repair and maintenance program. This program was founded in Quebec in 2019 but has since been rolled out in Ontario and British Columbia.[204] For automotive service technicians working at OEM-affiliated dealerships, specific EV service training is normally provided by partner OEMs. Some EV OEMs, such as Telsa, have also begun their own automotive service maintenance apprenticeship programs in Canada that are compliant with Red Seal automotive service technician requirements.[205]

There are other members of the automotive services team who will need to develop competencies in servicing and maintaining EVs. For example, a number of interviewees observed how specialized automotive diagnostic technicians will become increasingly sought after as vehicles, including EVs, become more computerized and reliant on digital systems. This will be especially true for independent automotive garages that cannot rely on OEM support for training and repair documentation.

201 Andrew Ross, "AARO Announces Ontario Funding for EV Technical Training," IndieGarage, May 3, 2022, https://www.indiegarage.ca/aaro-announces-ontario-funding-for-ev-technical-training/

202 "Intramural Innovation: AIA Canada to offer 'Innovation in Automotive Training' course at St. Lawrence College Cornwall," Collision Repair Mag, September 6, 2022, https://www.collisionrepairmag.com/intramural-innovation-aia-canada-to-offer-innovation-in-automotive-training-course-at-st-lawrence-college-cornwall/

203 "St. Clair College launching Ontario's first EV technician diploma program," Windsor Star, February 16, 2023, https://windsorstar.com/news/local-news/st-clair-college-launching-ontarios-first-ev-technician-diploma-program

204 Mehanaz Yakub, "NAPA Canada launching Quebec-made EV repair and maintenance program in B.C., Ontario," Electric Autonomy, Nov 17, 2022, https://electricautonomy.ca/2022/11/17/napa-canada-ev-repair-and-maintenance-program/

205 See: "Tesla Careers: START Program," accessed March 15, 2024, https://www.tesla.com/en_ca/careers/tesla-start

These diagnostic technicians will need to be skilled at reverse engineering diagnostic codes, often without complete repair documentation. One interviewee shared the experience of spending hours interpreting maintenance codes on various makes and models of EVs due to not having access to proper documentation.

Some interviewees also expressed interest in hiring in-house experts, such as EV battery service technicians and even electricians, in the future to help service and maintain EVs. Supporting roles, such as parts specialists and automotive service advisors, will also need to develop technical knowledge of EVs to advise customers and provide specialist support to their service teams. Experienced automotive services managers will also need to become familiar with the nuances of EV service and maintenance.

EV Charging Infrastructure: Workforce Gaps

By far, the most significant workforce gap related to charging infrastructure is the acute and long-running shortage of qualified electricians in Ontario. Electricians are needed to safely install public and private EV charging infrastructure. As a recent article by *CleanTechnica* notes, a new niche for electricians "installing residential EV chargers is growing exponentially as more and more EVs are produced and taken to the road."[206] This need for electricians extends to installing and maintaining public charging infrastructure as well.

From a downstream consumer perspective, a lack of widely available and reliable charging infrastructure in Ontario makes EVs a less viable vehicle option for some consumers and diminishes the experience of EV drivers as a whole. In this regard, the electrical trades are a linchpin that allows the downstream consumer segment of the EV value chain to function.

However, a 2023 report by Statistics Canada notes there is a significant shortage of qualified electricians throughout the country, noting over 5,000 job vacancies throughout Canada in 2022.[207] This acute shortage of electricians in Canada grew 51.6% between 2021 and 2022, according to Statistics Canada data.[208] *Industry journal Electrical Industry News Week*'s 2023 annual survey of Canadian electrical contractors found that labour shortages were contractors' third major business challenge, only proceeded by material sourcing and inflation.[209]

With a scarcity of electricians, public charging infrastructure projects, as well as the installation of private residential home chargers, are subject to delays and increased costs. Electricians carry out a multitude of essential electrical work related to construction and maintenance, so naturally, EV charger installation projects compete for electrician time with other important work.

206 "Installing EV Chargers Is A Booming Business For Electricians," CleanTechnica, May 7, 2023, https://cleantechnica.com/2023/05/07/installing-ev-chargers-is-a-booming-business-for-electricians/

207 Statistics Canada (Government of Canada), "Electricians: a current shortage," January 18, 2023, https://www.statcan.gc.ca/o1/en/plus/2768-electricians-current-shortage

208 Ibid.

209 "Electrician Job Vacancies & Assessing Labour Shortages in the Electrical Trade," Electrical Industry News Week, January 25, 2024, https://electricalindustry.ca/latest-articles/electrician-shortage-2023-sv/

EV non-profit Plug'n Drive stresses the importance of hiring a licensed electrician with ECRA/ESA certification and filing an ESA work notification before installing an EV charger.[210] There have been instances in Ontario of charging infrastructure being installed without proper permitting or the use of a qualified electrician. In 2023, Ontario's Electric Safety Authority (ESA) undertook a "safety blitz" to inspect charging infrastructure in the GTA and found 400 cases of chargers being installed without the proper permitting.[211] Improperly installed EV chargers represent both an electrical and fire hazard. With such hazards in mind, alongside the economic need for more electricians in Ontario, there is a public safety need for qualified electricians and electrical contractors to build out the province's charging infrastructure.[212]

The Electric Vehicle Infrastructure Training Program (EVITP), a comprehensive EV charger installation training program for licensed electricians, is offered by the National Electrical Trade Council (NETCO).[213] According to interviewees who are knowledgeable about charging infrastructure installation, EVIP provides a solution to a significant training gap for electricians. As EVs become more and more common across Ontario, there will be more demand for qualified electricians to install and maintain public and private charging infrastructure. Interviewees also noted a gap in Ontario colleges offering specific training for electricians and apprentices in installing EV chargers. On the question of offering more EV-related training for skilled trades, one interviewee stated, "I think colleges need to do a better job of upgrading what they're providing for the trades because, at least from what I've seen, a lot of them are still don't have any curriculum yet."

Environmental non-profit Pollution Probe advocates for enhanced standards for public EV charging station sites as an important step in improving the charging experience for EV drivers.[214] According to Pollution Probe's recommendations, public charging stations should include amenities, such as adequate street lighting, good signage, and considerations for accessibility.[215] Enhancing EV charging stations to improve EV driver experience is an important consideration as Ontario and the rest of Canada grapple with providing an adequate charging network. It also speaks to the potential for urban designers and architects to become more involved in developing public EV charging infrastructure.[216]

210 "Installing Your Charging Station," Plug'n Drive, accessed March 15, 2024, https://www.plugndrive.ca/charging-station-installation/.

211 "ESA Ramps Up Electric Vehicle Charging Safety in Ontario (Press Release)," Electrical Safety Authority, September 6, 2023, https://esasafe.com/newsroom-2023/esa-ramps-up-electric-vehicle-charging-safety-in-ontario/.

212 See: "Improperly Installed EV Chargers: A Safety Hazard and Missed Opportunity," Energize Ontario, N.D., https://www.energizeontario.ca/stories/improperly-installed-ev-chargers/.

213 See: National Electrical Trade Council, Electric Vehicle Infrastructure Training Program webpage, accessed March 15, 2024, https://netco.org/evitp-installers.

214 See: Pollution Probe, "2023 Canadian Electric Vehicle Owner Charging Experience Survey," Pollution Probe & Mobility Futures Lab, January 2024, https://www.pollutionprobe.org/wp-content/uploads/2024/01/EV-charging-report_2023_Jan24.pdf, 7.

215 Ibid.

216 For inspiration, see: "Electric vehicle charging stations," Dezeen, https://www.dezeen.com/tag/electric-vehicle-charging-stations/

PART V

⚡ POST-STREAM

Once an EV reaches the end of its useful life and is disposed of by the consumer, it will enter the post-stream phase of Ontario's EV value chain. In the post-stream, the EV will be disassembled, and its critical components, such as its battery, electronic systems, and other parts, will either be reused, repurposed, or recycled by specialist automotive and battery recyclers. Recovered EV materials, once recycled and reprocessed, can then be reinserted back into the EV value chain in a circular economy.

EV recycling is an oft-overlooked but important final step in the EV value chain, with significant growth potential over the coming decades. Globally, the post-stream recycling market for lithium ion batteries alone is estimated to grow to $35.1 billion USD by 2031.[217] The North American market for lithium ion battery recycling is projected to account for over $10.8 billion USD of this growing global market.[218] And these figures do not account for other valuable materials and vehicle components that can be recovered from EVs in the post-stream.

Globally, automotive recycling was an $81.2 billion USD market in 2022,[219] while globally electronics recycling was worth an estimated $37.2 billion USD in 2022.[220] Ontario, which is already home to thriving battery, automotive, and electronics recycling industries, can benefit from this immense economic opportunity while developing a circular economy within its EV ecosystem.

EV AUTOMOTIVE AND ELECTRONICS RECYCLING

Like any other vehicle at the end of its useful life in Ontario, an EV will be sent to an automotive recycler. Automotive recyclers source these vehicles from specialist dealers, insurance companies and auctions, and directly from the public.[221] Automotive disassembly workers will carefully disassemble the vehicle. An estimated 1,500 to 2,000 automotive recycling and dismantling businesses currently operate in Canada,[222] with around 500 of these companies operating in Ontario.[223] After the EV has been fully disassembled and all recoverable parts and components have been removed—alongside any environmentally harmful materials—the bulk of the EV will be flattened and shredded at one of 14 shedding facilities located in Ontario.[224] This shredded material will then be processed and either disposed of or recovered. An estimated 83% of a vehicle's materials can be recovered through recycling on average.[225]

217 "Lithium-ion Battery Recycling Market," Markets and Markets, April 2023, https://www.marketsandmarkets.com/Market-Reports/lithium-ion-battery-recycling-market-153488928.html

218 "North America Lithium-Ion Battery Recycling Market," Straits Research, accessed March 17, 2024, https://straitsresearch.com/report/north-america-lithium-ion-battery-recycling-market

219 "Vehicle Recycling Market," Markets and Markets, accessed March 17, 2024, https://www.marketsandmarkets.com/Market-Reports/vehicle-recycling-market-17692308.html

220 "Global Electronics Recycling Market to Reach $108.3 Billion by 2030," Research and Markets, March 2024, https://www.researchandmarkets.com/reports/2228028/electronics_recycling_global_strategic

221 Oakdene Hollins, "The Environmental Benefits of Green Recycled Parts in Ontario," Ontario Automotive Recyclers Association, https://oara.com/wp-content/uploads/2024/01/OARA-Final-GreenRecycledParts-report.pdf, 4.

222 Love Environment Inc., "Roadmap and Implementation Plan for the Management of End-of-Life Electric Vehicles in Canada: Appendices - Research Technical Papers to Support Roadmap Development," Automotive Recyclers of Canada, July 2022, https://autorecyclers.ca/wp-content/uploads/2024/01/Appendices-to-ARC-EV-Roadmap.pdf, 5.

223 Oakdene Hollins, "The Environmental Benefits of Green Recycled Parts in Ontario," Ontario Automotive Recyclers Association, https://oara.com/wp-content/uploads/2024/01/OARA-Final-GreenRecycledParts-report.pdf, 3.

224 "Canadian Auto Shredder Project," Automotive Recyclers of Canada, accessed March 17, 2024, https://autorecy clers.ca/canadian-auto-shredder-project/

225 "Auto Recycling: Everything You Need to Know," Driving, May 23, 2018, https://driving.ca/auto-news/news/how-it-works-vehicle-recycling

In Canada, an estimated 1.6 million vehicles reach the end of their useful life annually, with 95% of these vehicles destined for recycling.[226] While most vehicles that are recycled in Ontario today are traditional ICEs, as EVs become more common as the current crop of EVs being built today reach the end of their lifecycles, experts interviewed posit that EVs will begin to make up a greater portion of Ontario's recycled vehicles in the next decade.[227]

The current generation of EVs make heavy use of electronics and digital systems. As one interviewee quipped, an EV is "a moving computer." Once an EV is dismantled, the electronic vehicle components, which are not recovered and sold as used parts, will need to be recycled or otherwise disposed of.

Within Canada, electronics are subject to end-of-life management regulations and must be responsibly recycled once they reach the end of their useful lives.[228] In most Canadian provinces, these regulations cover some, but not all, electronic vehicle components. However, in Ontario, most vehicle electronic components do not fall under provincial electronics end-of-life management regulations, with exceptions to this being some audio-visual equipment and aftermarket electronic parts.[229] EV batteries and their electronic subsystems are not covered by end-of-life electronics regulations in Ontario. However, Ontario does have a growing battery recycling industry.

AN EV CIRCULAR ECONOMY FOR ONTARIO

The Ellen MacArthur Foundation describes a circular economy as "a system where materials never become waste and nature is regenerated. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting."[230] Under such an economic model, products that reach the end of their useful lives are repurposed, reused, or recycled. The recycled materials are stewarded and formed into new products, while supply chains incorporate recycled materials by design when producing new products.

The Government of Canada states that the "circular economy retains and recovers as much value as possible from resources by reusing, repairing, refurbishing, remanufacturing, repurposing, or recycling products and materials."[231] The Ontario government's 2017 Strategy for a Waste-Free Ontario circular economy strategy document calls for the establishment of circular economies throughout the economy to promote innovation, enhance environmental protection, and increase the province's economic competitiveness.[232] The province's circular economy strategy includes improved end-of-life vehicle processing standards.[233]

226 "The low-down on Canada's automotive recycling industry," Canadian Auto Recyclers Magazine, August 21, 2019, https://canadianrecycler.ca/the-low-down-on-canadas-automotive-recycling-industry/

227 "How Long Does an Electric Car Battery Last?" EV Connect, November 8, 2024, https://www.evconnect.com/blog/how-long-does-an-electric-car-battery-last; Liz Najman, How Long Do Electric Car Batteries Last? March 2023, Recurrent, https://www.recurrentauto.com/research/how-long-do-ev-batteries-last

228 See: Kaitlyn Carr, Allison Clark, & Mairead Matthews, "Building a Sustainable ICT Ecosystem: Strategies and Best Practices for Reducing Environmental Harms in a Digital World," Information and Communications Technology Council (ICTC), January 2024, https://ictc-ctic.ca/reports/building-a-sustainable-ict-ecosystem, 43.

229 See: Electronic Products Recycling Association, "March 1, 2024 Steward Update," March 2024, https://epra.ca/what-is-a-steward/product-definitions-fees-clarification-protocols, 21-22.

230 Ellen MacArthur Foundation, "What is a circular economy?" accessed March 17, 2024, https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

231 Government of Canada, "Circular economy: What is the circular economy?" last update: December 23, 2022 https://www.canada.ca/en/services/environment/conservation/sustainability/circular-economy.html

232 Government of Ontario, "Strategy for a Waste-Free Ontario: Building the Circular Economy," February 2017, https://www.ontario.ca/page/strategy-waste-free-ontario-building-circular-economy, 6.

234 Ibid., 24.

With the majority of EV materials and components parts being recyclable, including the valuable battery packs, and acknowledging the province's already significant vehicle, electronics, and battery recycling industries, Ontario can establish a circular economy within its EV value chain. Within such a circular economy, many of the materials recovered during EV recycling can be reintroduced back into the supply chain, such as the critical minerals used in lithium ion battery production.[234]

Yet, globally, it's estimated that only 5% of lithium ion batteries of all types are recycled today.[235] This is despite an estimated 95% of lithium ion battery materials can be recovered and turned into new batteries.[236] Other recovered EV components and materials—which recent analysis by EY suggests represent 60% of the total value of materials from a recycled EV—can also be reintroduced into the EV supply chain.[237] Recycling EV batteries and other components can reduce EV manufacturing carbon intensity and reduce automotive supply chain risk.[238] Recovering scarce EV critical minerals, such as lithium, could also reduce pressure on the critical minerals mining industry and ultimately reduce the amount of critical minerals materials which will need to be mined in the coming decades as more EVs hit the road and more EV batteries are manufactured.

234 See: EY, "The EV Circular Economy: The Promise and Hurdles of Battery Recycling and Repurposing," Informa Tech Automotive Group & WardsAuto, December 2023, https://assets.ey.com/content/dam/ey-sites/ey-com/en_us/topics/emobility/ey-the-ev-circular-economy-the-promise-and-hurdles.pdf

235 American Chemical Society, "Lithium Ion Battery Recycling: A Review of the Current Methods and Global Developments," CAS Insights, September 2022, https://www.cas.org/resources/cas-insights/sustainability/lithium-ion-battery-recycling

236 Canadian Renewables Association, "Sustainable Energy: Recycling Renewables (Fact Sheet)," April 2021, https://renewablesassociation.ca/wp-content/uploads/2021/04/Recycling-Batteries-English-Web.pdf, 1.

237 Mark Weick & Nicole Ray, "Beyond batteries: Unlocking the value of circularity in electric vehicles," April 2023, https://www.ey.com/en_us/climate-change-sustainability-services/beyond-batteries-electric-vehicle-circularity

238 Ibid.

EV BATTERY RECYCLING AND REPURPOSING

As an EV battery degrades over its lifecycle, it affects both vehicle range and acceleration.[239] Just like a lithium ion laptop or cell phone battery, eventually, an EV battery will degrade so much that it will no longer have the capacity to hold a useful charge. EV batteries are also often retired after an EV is physically damaged in a traffic accident.[240] At this point, the battery will be recycled, repurposed, or discarded.[241] While the number of used EV batteries is comparatively small today, the overall number is expected to accelerate into the 2030s.[242]

From an environmental sustainability and circular economy perspective, it is far preferable for an EV battery to be repurposed or recycled than disposed of. As noted, used EV batteries are far from a waste product, but rather an economically valuable resource that can be recycled into their component materials and reintroduced into the EV supply chain or repurposed into another role. Interviewees from Ontario's automotive recycling industry reflected that in the past, automotive recyclers struggled to deal with EV batteries and would often pay to have the batteries disposed of, but more recently, they have begun to see EV batteries as a valuable asset. As a 2022 article by the Automotive Recyclers of Canada notes, "EV batteries are not waste; they are assets that more and more industries are clamouring for."[243]

If an EV battery is repurposed, it could be used in applications such as distributed energy storage.[244] Analysis by SAE International notes that repurposed EV batteries could remain useful in second-life applications for a decade or more if properly maintained.[245]

If a battery is not repurposed, it can be recycled at a specialized battery recycling facility. A battery destined to be recycled will normally be removed from its casing and subjected to a variety of industrial processes to safely discharge any remaining power in the battery, disassemble the battery cells and separate plastics, steel, copper, aluminum, and resins, and then shred the component battery cell materials to produce black mass.[246] The black mass will consist of a mixture of battery metals, such as lithium, nickel, cobalt, and manganese, which will account for up to 50% of the battery's original weight.[247]

239 Hanjiro Ambrose, et al., "Battery Second-Life: Unpacking Opportunities and Barriers for the Reuse of Electric Vehicle Batteries," CalRecycle, AB2832 Working Group, May 2020, https://equation.wpengine.com/wp-content/uploads/2020/05/AG-Reuse-Brief_5-12-F.pdf

240 "Scratched EV battery? Your insurer may have to junk the whole car," CTV News, March 20, 2023, https://www.ctvnews.ca/autos/scratched-ev-battery-your-insurer-may-have-to-junk-the-whole-car-1.6320744

241 EY, "The EV Circular Economy: The Promise and Hurdles of Battery Recycling and Repurposing," 4.

242 NGen, "Canadian Automotive Supplier Capability and EV Value Chain Analysis," March 2022, https://ngen.ca/hubfs/NGen%20EV%20Report%20March%202022.pdf, 27.

243 "Opportunities and challenges for the auto recycling industry," Automotive Recyclers of Canada, March 23, 2022, https://autorecyclers.ca/opportunities-and-challenges-for-the-auto-recycling-industry/

244 Hanjiro Ambrose, et al., "Battery Second-Life: Unpacking Opportunities and Barriers for the Reuse of Electric Vehicle Batteries," 5-7.

245 Jeremy S. Neubauer, et al., "A Second Life for Electric Vehicle Batteries: Answering Questions on Battery Degradation and Value," SAE International, 2015, https://ww w.nrel.gov/docs/fy15osti/63524.pdf

246 Aqua Metals, "What Exactly is Lithium Battery 'Black Mass'," Lithium-Ion Battery Recyclopedia, accessed March 17, 2024, https://www.aquametals.com/recyclopedia/what-exactly-is-black-mass/

247 Ibid.

As every model of lithium ion battery is different, the exact composition of the black mass will vary depending on the battery feedstock used.[248] From there, the black mass can be reprocessed and reintroduced into the EV battery supply chain, creating a circular economy for lithium ion batteries. S&P Global projects that black mass will become an increasingly important component of the battery supply chain as the global EV industry grows.[249] Under the EU's Batteries Regulation, EV batteries produced or distributed in the EU market will be required to contain minimal thresholds of recycled battery metals.[250]

Repurposing and recycling EV batteries requires a skilled workforce that is able to carry out complex refurbishment and battery processing work. Occupations involved in the refurbishment and repurposing of EV batteries include battery technicians and repairers, electronics assemblers and electricians, quality engineers/specialists, warranty managers and auditors, and inspection and test personnel. Battery recycling requires specialist engineers, battery technicians, and health and safety managers, among other roles. As the EV battery repurposing and recycling industries are still in their early days, there are likely to be changes to these industries' talent needs. The ALBATTS project provides a high-level overview of battery repurposing and recycling roles, along with high-level competencies essential in the battery repurposing and recycling industries; see Tables 11 and 12.

Table 11: Jobs/Roles across the EV Battery Repurposing and Recycling Industries

EV BATTERY REPURPOSING / SECOND LIFE	Cell inspection technician	Battery test technician	Battery repairer	Electrician assembler	Service technician	Quality specialist
EV BATTERY RECYCLING	Battery disassemble technician	Recycling engineer	Safety manager	Compliance engineer	Warranty manager	Recycling auditor

Source: Adapted from Jakub Stolfa, "Emerging skills needs from ALBATTS project on the battery value chain and related initiatives," in Skills and Education for the Emerging Battery Economy: European Challenges and Solutions, June 2021, 53.

Table 12: Competencies across the EV Battery Repurposing and Recycling Industries

EV BATTERY REPURPOSING / SECOND LIFE	Communicate with customer	Repair battery components	Homologation (recertification)	Legislative / regulations	Testing	Safety procedures
EV BATTERY RECYCLING	Risk management	Legislative regulations/ compliance	Standardization	Inspect quality	Legislative	Health and safety

Source: Adapted from Jakub Stolfa, "Emerging skills needs from ALBATTS project on the battery value chain and related initiatives," in Skills and Education for the Emerging Battery Economy: European Challenges and Solutions, June 2021, 51.

248 Ibid.

249 Christopher Davis, "Black mass recycling critical to battery metals supply chain's development," S&P Global, October 11, 2023, https://www.spglobal.com/commodityinsights/en/market-insights/blogs/metals/101123-black-mass-recycling-critical-to-battery-metals-supply-chains-development

250 See: "New EU Batteries Regulation: introducing enhanced sustainability, recycling and safety requirements," White & Case, August 2, 2023, https://www.whitecase.com/insight-alert/new-eu-batteries-regulation-introducing-enhanced-sustainability-recycling-and-safety

EV Battery Recycling in Ontario

EV battery recycling in Canada is rapidly developing, with a number of projects currently in operation or under development. Toronto-based Li-Cycle, a global leader in lithium ion battery recycling, operates a battery recycling facility in Kingston, ON.[251] The Kingston spoke facility produces black mass from recycled lithium ion batteries, which can then be reintegrated into the EV battery supply chain in Southern Ontario.[252] Li-Cycle has become a globally notable firm in the lithium ion battery recycling industry, and in addition to its Kingston facility, it currently operates several other "spoke" battery recycling facilities in the United States, the United States, Germany, France, and Norway. The company also has two "hub" facilities that will turn black mass into reprocessed battery materials under development in Portovesme, Italy and Rochester, New York.[253] Battery recycling startup Electra Battery Materials Corporation is also currently operating facilities in Ontario and has recently announced the development of a battery materials park in partnership with the Three Fires Group, to be located in Temiskaming Shores, ON.[254] Other companies engaged in Canada's lithium ion battery recycling industry include Lithion Recycling, RecycLiCo, and Retriev Technologies.[255]

POST-STREAM LABOUR SUPPLY AND DEMAND

While recycling in manufacturing has been practised in Ontario for years, its role in the province's EV value chain is still emerging. As noted above, recycling and reclamation of used battery materials will be an integral part of building a circular economy in the EV industry.

ICTC's employer survey asked businesses from the post-stream part of the EV value chain how they think their company's operations will be impacted by Ontario's EV industry. The greatest percentage of respondents indicated that Ontario's EV industry will have a positive impact on the supply of materials needed for production, as well as the demand for their products and services. Across other dimensions, there was less consensus amongst respondents about what effects were likely to occur. However, there was more consensus among recycling respondents about whether the above outcomes will be positive or negative. Respondents were asked a follow-up question: Do you believe that the impact of Ontario's electric vehicle industry will be positive, negative, or neutral?

251 "Ontario Spoke," Li-Cycle, accessed May 17, 2024, https://li-cycle.com/ontario-spoke/

252 See: "How this tiny Ontario city became an important node in the global supply chain for critical minerals," Financial Post, May 29, 2023, https://financialpost.com/commodities/energy/renewables/how-kingston-global-hub-recycling-critical-minerals

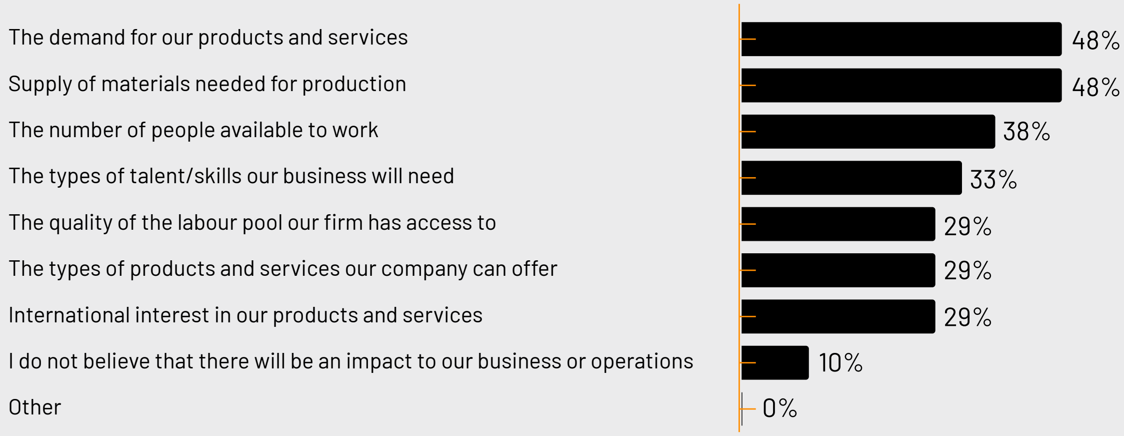
253 "Our Spoke & Hub network continues to grow and develop," Li-Cycle, accessed March 17, 2024, https://li-cycle.com/operations/

254 "Electra announces Three Fires Group investment in battery recycling project," Electric Autonomy Canada, July 5, 2023, https://electricautonomy.ca/2023/07/05/electra-three-fires-group-investment/

255 See: "About," Lithion, 2024, accessed March 13, 2024, https://www.lithiontechnologies.com/lithium ion-battery-recycling-plant/; "Enabling On-Site Lithium ion Battery Recycling Globally," RecycLiCo Battery Materials Inc., accessed March 13, 2024, https://recyclico.com/technology/; "Retriev Technologies," Imagine Kootenay, accessed March 17, 2024, https://imaginekootenay.com/employers/retriev-technologies-trail/

Figure 14: Automotive and Battery Recycling: Effect of the EV Industry on Business?

RECYCLING: INVESTMENT IN ONTARIO'S EV INDUSTRY WILL HAVE AN IMPACT ON ...



Data Source: ICTC EV Industry Workforce Survey. (N=21)

For those respondents who believed the EV industry would affect their business, they overwhelmingly thought that there would be positive outcomes resulting from the emerging industry. The survey shows that 90% of respondents believed the EV industry would have positive effects on the demand for their services and the supply of production inputs. Similarly, while fewer respondents believe the EV industry would affect the number of people available to work (38%) and the quality of the talent (29%), those that did believe there would be impacts believed the impacts to be positive. Overall, those in the recycling sector were generally quite optimistic about the advent of the EV industry.

Figure 15: Automotive and Battery Recycling: Favourable Outcomes of EV Ecosystem Development

RECYCLING: FAVOURABLE OUTCOMES

Data Source: ICTC EV Industry Workforce Survey. (N=21)

In addition to conducting a survey, ICTC used insight from its primary and secondary research to map Statistics Canada's National Occupational Classifications (NOC) codes to known occupations in the post-stream segment of the EV value chain (see Table 13).[256] This enabled ICTC to use Statistics Canada's Labour Force Survey to track employment in post-stream roles in Ontario over time, as well as the unemployment rate for Ontario's post-stream labour force.

Table 13: NOC Codes and Job Titles Pertaining to the Post-Stream Component of the EV Value Chain

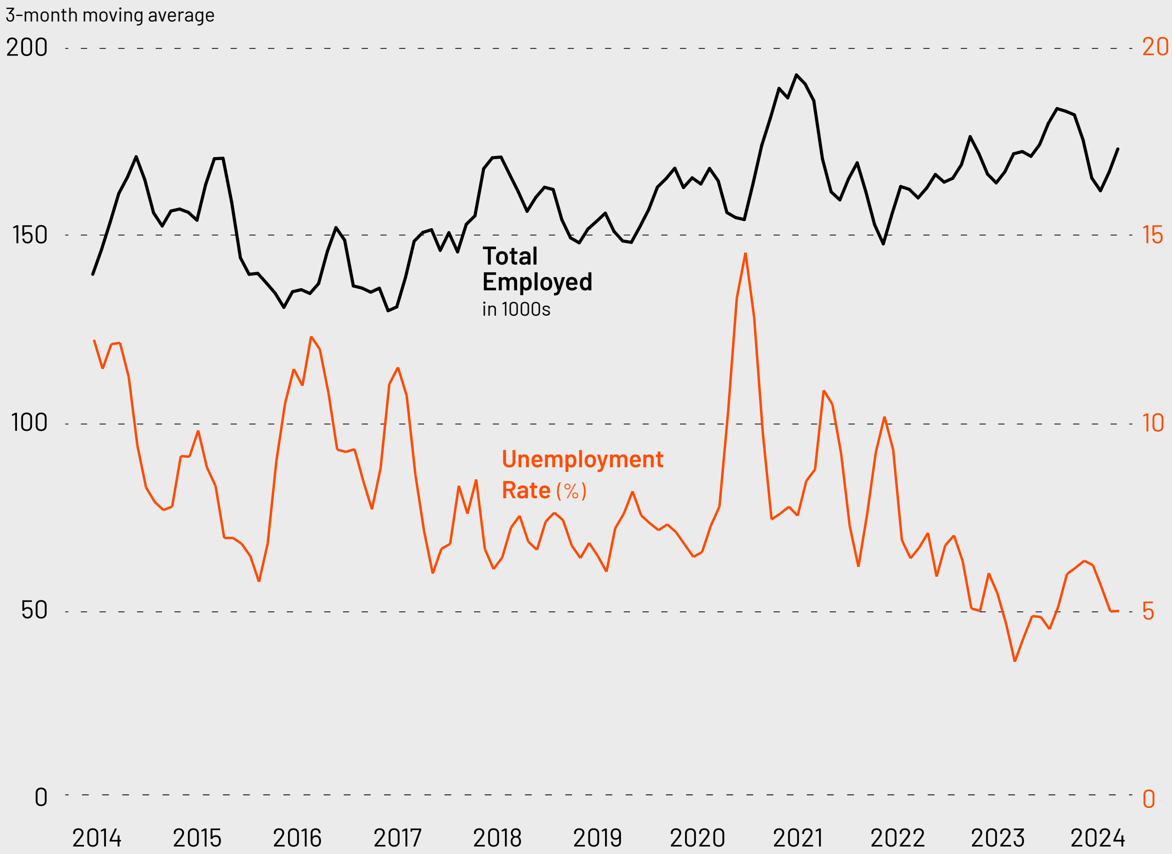
NOC CODES		JOB TITLES
21101	Chemists	Automotive disassembler
21109	Other professional occupations in physical sciences	Chemist
21320	Chemical engineers	Chemical Engineer
72200	Electricians (except industrial and power system)	Ecologist
75101	Material handlers	Electrician
94110	Chemical plant machine operators	General Labourer
95102	Labourers in chemical products processing and utilities	Industrial Mechanic
95109	Other labourers in processing, manufacturing and utilities	Material Handler
		Materials Manager
		Operations Manager
		Parts Advisor
		Plant Operator
		Project Manager
		Warehouse Associate
		Warehouse Operator

Data source: NOC Codes identified using Statistics Canada, ICTC analysis.
Job titles identified using publicly available data, ICTC analysis.

The data shows that employment in post-stream roles has been quite volatile, something that can dissuade individuals from seeking careers in this industry. This volatility may be explained by the low level of employment in post-stream roles in comparison to other types of roles; out of all of the streams in the EV value chain, including digital economy employment, employment in post-stream-related occupations amounts to the fewest roles. Fewer employers, and thus a smaller industry overall, may make the post-stream phase of the EV value chain more sensitive to exogenous shocks, such as changes in the composition of the Ontario economy. Unemployment in post-stream roles has hovered between 5% and 15% in the past 10 years, though it has notably been lower since the end of 2021, fluctuating between 4% and 7%; see Figure 16.

256 See: Javier Colato & Lindsey Ice, "Charging into the future: the transition to electric vehicles," US Bureau of Labour Statistics, Beyond the Numbers, vol. 12, no. 4, February 2023, https://www.bls.gov/opub/btn/volume-12/charging-into-the-future-the-transition-to-electric-vehicles.htm; James Hamilton, "Careers in Electric Vehicles," US Bureau of Labor Statistics, September 2011, https://www.bls.gov/green/electric_vehicles/electric_vehicles.pdf, 5-12; Shannon M. Sedgwick & Christine Cooper, "Electric Vehicles: The Market and Its Future Workforce Needs," Los Angeles County Economic Development Corporation, August 2012, https://www.pacific-gateway.org/ev_pgwin_final.pdf, 33; "Electric Vehicle-Battery Value Chain Talent Requirements," Invest Windsor/Essex, December 2021, https://www.workforcewindsoressex.com/wp-content/uploads/2021/12/Electric-Vehicle-Battery-Value-Chain-Talent-reduced.pdf

Figure 16: Ontario Residents Engaged in Post-Stream Occupations Relevant to the EV Value Chain



Data Source: Statistics Canada Labour Force Survey, ICTC Analysis.

Because the post-stream components of the EV value chain are still emerging, it will be important to watch how employment in this industry changes. The emergence of firms in the Ontario landscape and increases in the ubiquity of EVs can have positive effects on the magnitude of labour engaged in this space. As the workforce grows in the post-steam components of the EV industry and the battery and automotive recycling industries grow, it is possible that there will be less volatility in employment. It will be important to monitor how demand for talent changes and ensure that there are barrier-free pathways to employment in these areas as post-stream EV recycling industries continue to develop.

EV Recycling: Workforce Gaps

Representatives from the automotive recycling industry interviewed for this study noted that as more EVs reach the end of their useful lives and end up with automotive recyclers, there will be incremental changes required throughout the industry. When compared to the other parts of the EV ecosystem in Ontario, these needed changes have a longer lead time, and EVs on the road today still have many years left in their useful lives. The automotive recycling industry still has some time to adapt.

However, this does not mean change will come easily. As noted by interviewees, most automotive recyclers in Ontario are small businesses that may lack the capacity to make major investments to adapt to change and stay competitive. Dismantling EVs poses special challenges due to the battery packs and the way in which many new EVs are designed, making automotive disassembly challenging.

Battery packs create a significant safety concern for vehicle disassemblers. As one interviewee remarked on the potential safety hazards, "You see the power of these batteries and what they can do to a human being who doesn't know what they're doing." EV battery safety training and new disassembly guidelines and processes will need to be developed as more EVs require recycling in the future.

As those in the automotive service industry have found, some OEMs are not always forthcoming with technical documentation for many EV models. This can make disassembly challenging. Some disassemblers have begun using emergency responder guides to assist them in their EV disassembly work.[257] Disassemblers have also pursued training targeted toward automotive service technicians and even first responders to help them safely disassemble EVs.[258] Industry groups within the automotive recycling industry have also begun offering industry training and shared resources to upskill the automotive recycler workforce on EV disassembly.[259] The Automotive Recyclers of Canada have produced an "EV industry roadmap" to create industry training nationally for automotive disassemblers to safely and effectively disassemble EVs.[260]

Interviewees also observed how automotive disassemblers working on EVs will need to be relatively more skilled due to the increased complexity of EVs disassembly when compared to disassemblers working on ICEs. These interviewees noted EV disassemblers will need to have superior skills in disassembly, technical documentation, and attention to detail. EV disassemblers will also need to have significant knowledge of the different models of EVs that they commonly encounter on the job.

Automotive recyclers are also adopting more digital technology to improve their business operations. Interviewees knowledgeable on the matter noted how the industry is utilizing digital parts inventory management systems, predictive analytics for inventory management, as well as online marketplaces and auctioning for high-value items such as used EV batteries. Automotive recyclers also require support from software developers who can work with APIs to link their parts inventory systems together to create such marketplaces.

257 See: "Emergency Response Guides," National Fire Protection Association, accessed March 18, 2024, https://www.nfpa.org/education-and-research/emergency-response/emergency-response-guides

258 For example, see: National Fire Protection Association, "Electric Vehicle Safety Online Training," accessed March 18, 2024, https://www.nfpa.org/for-professionals/training-for-me/alternative-fuel-vehicles-training/electric-vehicles

259 For example, see: "EV/Hybrid Vehicle Dismantling Resources," Automotive Recyclers of Canada, accessed March 18, 2024, https://autorecyclers.ca/ev-hybrid-vehicle-dismantling-resources/

260 Automotive Recyclers of Canada, "EV Industry Roadmap," July 2022, https://autorecyclers.ca/ev-industry-roadmap/

DIGITAL ECONOMY WORKERS IN ONTARIO'S EV VALUE CHAIN

Given the speed of technology adoption across the economy, digital economy workers play a role in all segments of the EV value chain. Digital economy roles differ from other roles that are in demand in the EV value chain in that they focus explicitly on the design, development, maintenance, and use of digital technology solutions for the EV industry. This includes roles like software developer, computer programmer, embedded software engineer, computer engineer, hardware engineer, computer network technician, data analyst, and data scientist. While the types of digital economy roles that are in demand in each segment are quite similar—bearing job titles like software developer, hardware engineer, and data scientist—the digital technology solutions that digital economy workers design, build, and maintain in each phase of the EV value chain are different:

UPSTREAM

Digital technology workers in the upstream phase of the EV value chain design, build, and maintain solutions for natural resource exploration, mining exploration, mining operations, and minerals processing. These solutions use technologies like remote sensing, 3D and geographic data, IoT, robotics, and AI to locate large concentrations of minerals, map them, determine the feasibility of mining them, plan how to access them, and, in some cases, mine them. They may also help to ensure safety, efficiency, and sustainability in mining projects. For example:

- Exiro Minerals, based in Toronto and Sudbury, ON uses proprietary technology and data to identify "high-quality exploration assets with tier 1 and 2 discovery potential." [161]
- Quantec Geoscience, based in Toronto, uses electrical and electromagnetic earth imaging techniques to help clients map mineral resources in extensive detail, reducing the risk associated with mineral exploration and increasing returns.[162]
- Copperstone Technologies, based in Edmonton, AB manufactures industrial autonomous robots to conduct a variety of activities that are essential to mining, such as geotechnical surveys, subsurface investigations, water surveys, and environmental monitoring.[163]
- MineSense, based in Vancouver, BC, develops technology and data solutions that help mining companies increase their output and profitability while minimizing their impact on the environment, such as land use change, water consumption, and energy use.[164]

Once natural resources have been mined, digital technology solutions help track raw materials through the supply chain as they are processed and eventually used to manufacture EV parts and components.

MIDSTREAM

Digital economy workers in the midstream phase of the EV value chain use technology to design and engineer new vehicles. Vehicle manufacturers incorporate a range of technologies into the design process, including computer-aided design (CAD) software, product data management software, 3D simulation software, virtual and augmented reality, and 3D printing. During the manufacturing stage, digital economy workers—such as mechanical engineers, hardware engineers, and specialists in robotics process automation—build advanced machinery and robotics solutions that can be incorporated by manufacturers to automate or increase the efficiency of repetitive tasks.

In addition to this, auto manufacturers need to be increasingly proficient at incorporating information and communications technologies into vehicles themselves. Modern vehicles rely on a complex array of information and communications technologies, including vehicle software, data, IoT, and cybersecurity features. Software is increasingly used by auto manufacturers to manage vehicle operations, add new functionality to vehicles, and enable new features.[265]

For example, software is being used to enable autonomous driving; improve in-vehicle entertainment systems; optimize vehicle performance; manage EV batteries; give auto manufacturers and mechanics better insight into vehicle performance, diagnostics, and maintenance; push new features to cars that have already been purchased through software updates; and improve vehicle safety, for example, via anti-collision systems, driver assistance features, and vehicle-to-vehicle and vehicle-to-infrastructure communication.[266]

To build and maintain vehicle software, auto manufacturers need employees who are familiar with both user software applications and embedded operating systems, and who can integrate these into vehicle hardware.[267] Because of this, the auto manufacturing industry is experiencing growing demand for roles like software developer, embedded software engineer, hardware engineers, data scientists, and cybersecurity specialist.[268]

DOWNSTREAM

Examples of digitalization in the downstream segment of the EV value chain include the use of websites to market and sell vehicles to consumers or catalogue and sell vehicle parts to auto repair shops; the use of information and communications technologies to manage vehicles remotely and push new updates to vehicle software; the use of vehicle telemetry to track performance data and manage vehicle fleets; the use of vehicle software to diagnose problems with vehicles and facilitate repairs; and the use of software, cloud technologies, and digital payment solutions to manage EV chargers. To provide these types of solutions, firms need access to a range of digital economy workers, including digital marketing and e-commerce specialists, software developers, web developers, cloud administrators, cloud engineers, data analysts, and data scientists.

POST-STREAM

Digital economy workers in the post-stream segment of the EV value chain build technology solutions related to the reuse, recycling, and disposal of EVs and EV parts. For example, they might build an e-commerce platform that catalogues, tracks, and sells used vehicles or used parts or helps stakeholders in the automotive industry locate suitable options for battery recycling and disposal. Interviewees from the automotive recycling industry noted the important role a used EV battery digital marketplace would have in making their industry more efficient.

Supply and Demand for Digital Economy Workers Across the EV Value Chain

To analyze the demand for digital economy roles in Ontario's EV value chain, ICTC used insight from its primary and secondary research to map Statistics Canada's National Occupational Classifications (NOC) codes to known occupations in the digital economy segment of the EV value chain (see Table 14).[269] This enabled ICTC to use Statistics Canada's Labour Force Survey to track employment in digital economy roles in Ontario over time, as well as the unemployment rate for the digital economy labour force.[270]

Table 14: NOC Codes and Job Titles Pertaining to the Digital Economy

NOC CODES		JOB TITLES
20012	Computer and information systems managers	Cybersecurity Analyst
21211	Data scientists	Cyber Security Engineer
21220	Cybersecurity specialists	Cyber Risk Consultant
21222	Information systems specialists	Data Analyst
21223	Database analysts and data administrators	Data Engineer
21230	Computer systems developers and programmers	Data Scientist
21231	Software engineers and designers	Embedded Software Developer
21232	Software developers and programmers	Front End Developer
21233	Web designers	Hardware Engineer
21234	Web developers and programmers	IT Manager
21311	Computer engineers (except software engineers and designers)	IT Project Manager
22220	Computer network and web technicians	IT Specialist
22222	Information systems testing technicians	IT Support Technician
72200	Electricians (except industrial and power system)	IT Systems Administrator
		Product Manager
		SharePoint Developer
		Software Architect
		Software Developer
		Software Engineer

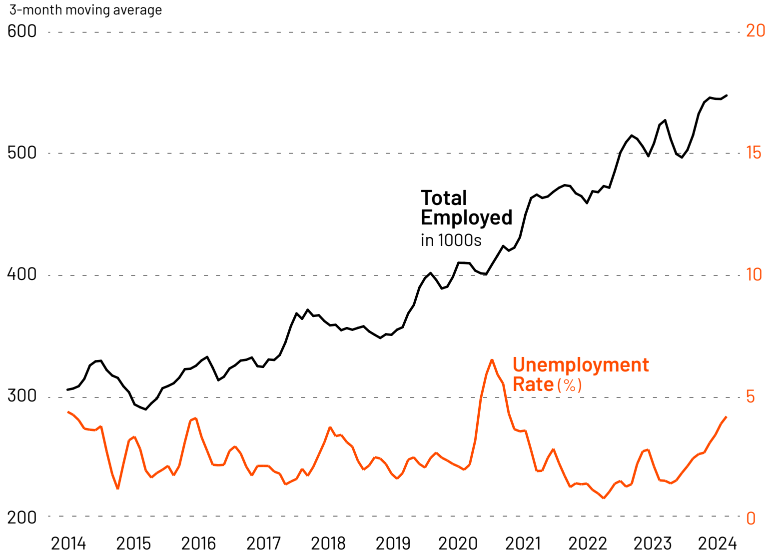
Data source: NOC Codes identified using Statistics Canada, ICTC analysis.
Job titles identified using secondary data sources, ICTC analysis.

As seen in Figure 17, the number of Ontarians employed in digital economy roles relevant to the EV industry has grown consistently over the last 10 years. In Ontario alone, there are approximately 550,000 people employed in EV-relevant digital economy roles, representing close to one-half of all digital economy employment in Ontario.[271] Moreover, despite some fluctuations, employment in these roles lacks the extreme level of volatility that is visible in upstream and post-stream parts of the EV value chain.

While this data points to a growing supply of digital economy talent, it is important to note that due to the scale of digitalization in the modern economy, digital economy roles that are in demand in the EV industry are also in demand in many other high-technology industries, such as finance technology, clean technology, agriculture and food technology, and health technology, to name just a few. Because of this, EV firms face considerable competition when trying to hire and retain digital economy workers. Many firms, particularly smaller players, may struggle to match the higher wages or benefits provided by larger and more established companies.[272]

Figure 17: Ontario Residents Engaged in Digital Technology Occupations Relevant to the EV Value Chain

Data source: Statistics Canada Labour Force Survey, ICTC Analysis



High competition for digital economy workers is evident in Figure 17. In comparison to other parts of the EV value chain, over the last 10 years, Ontario's digital economy labour force has generally had the lowest unemployment rate, hovering close to zero percent multiple times over the past decade. This suggests that at any given time, there are very few digital economy workers unemployed and looking for work, and therefore, very few workers are available to employers who are hiring. This could prove to be a significant challenge for EV ecosystem employers due to digital economy workers' ubiquity throughout the EV value chain.

Additionally, given that digital economy workers are needed in all areas of the economy, the EV ecosystem may face challenges in creating awareness among digital economy workers about the employment opportunities that exist across the EV value chain. Indeed, prospective talent may not realize that there is a need for their skills and competencies in the EV industry.

Ensuring that there is an adequate supply of professionals who have the skills and competencies to fill digital economy roles will be important in supporting the growth and success of Ontario's industry, as will ensuring digital economy workers are aware of and interested in EV employment opportunities. Needless to say, because digital economy roles are important to Ontario's EV ecosystem, as well as the rest of the Ontario economy, strong programs supporting the growth and development of the digital economy labour force will be paramount.

261 "Exiro Minerals Overview," Pitchbook, accessed March 15, 2024, https://pitchbook.com/profiles/company/437486-14#overview

262 "Profile and Experience," QUANTEC Geoscience, accessed March 15, 2024, https://quantecgeo.com/about-us-2/

263 "About," Copperstone Technologies, accessed March 15, 2024, https://copperstonetech.com/about/

264 "About Us," Minesense, accessed March 15, 2024, https://minesense.com/about-us/

265 "Software-Defined Vehicles," 2024, Blackberry QNX, https://blackberry.qnx.com/en/ultimate-guides/software-defined-vehicle

266 Ibid.

267 Ibid.

268 "Canada's Automotive Technology Clusters: Labour Market Characteristics and Regional Specializations," Future of Canadian Automotive Labourforce (FOCAL), December 2020, https://www.futureautolabourforce.ca/wp-content/uploads/2020/12/Canadas-Automotive-Technology-Clusters.pdf; Shannon M. Sedgwick & Christine Cooper, "Electric Vehicles: The Market and Its Future Workforce Needs," Los Angeles County Economic Development Corporation, August 2012.

269 See: Javier Colato & Lindsey Ice, "Charging into the future: the transition to electric vehicles," US Bureau of Labour Statistics, Beyond the Numbers, vol. 12, no. 4, February 2023; James Hamilton, "Careers in Electric Vehicles," US Bureau of Labor Statistics, September 2011, 5-12; Shannon M. Sedgwick & Christine Cooper, "Electric Vehicles: The Market and Its Future Workforce Needs," Los Angeles County Economic Development Corporation, August 2012, 33; "Electric Vehicle-Battery Value Chain Talent Requirements," Invest Windsor/Essex, December 2021.

270 ICTC maintains its own definition of NOCs associated with the digital economy. Jobs needed for the EV value chain were first identified using primary and secondary sources, and those that also belong to ICTC's Digital Economy NOCs were analyzed in this section.

271 As of November 2023, there were approximately 1.2 million people employed in the Digital Economy in Ontario. See: "eTalent Canada," Information and Communications Technology Council (ICTC), accessed March 13, 2024, https://etalentcanada.ca/locations/ontario

272 Mairead Matthews & Faun Rice, "Context Matters: Strengthening the Impact of Foreign Investment on Domestic Innovation," Information and Communications Technology Council (ICTC), March 2022, https://ictc-ctic.ca/reports/context-matters, 40.

CONCLUSION

Ontario is home to a quickly developing EV industry that is poised to be a generational economic opportunity. While Ontario's EV industry is centred on the EV battery manufacturing and vehicle assembly facilities, which are currently under construction or being retooled in Southern Ontario and the GTA, the wider EV ecosystem provides opportunities for most regions of the province. This EV ecosystem includes not only EV battery, automotive parts, and vehicle manufacturing, but also critical minerals mining and processing, charging infrastructure installation and management, automotive sales and marketing, vehicle service and maintenance, and battery and automotive recycling.

In addition to these EV-specific segments, firms from Ontario's digital economy also produce automotive software, data services, and other digital technologies that help Ontario build the EVs of the future. These different segments of Ontario's EV ecosystem demand significant inputs of labour and talent for Ontario to benefit from the full potential of its EV industry. Indeed, Ontario is one of the few jurisdictions globally that has the potential to participate in the entire EV value chain.

This study assesses the workforce and human capital implications of Ontario's emerging EV industry and its effect on jobs and skills throughout the upstream, midstream, downstream, and post-stream components of the province's EV value chain. While most of the jobs that will be created as the province's EV industry grows will align with existing occupations, there will be changes to some occupations within the EV ecosystem. For example, automotive salespeople will need to develop EV product knowledge, improve their understanding of EV consumer behaviour, and learn to seamlessly integrate with their dealership's digital marketing and e-commerce team to successfully sell EVs.

This is good news, as it shows that Ontario already has the skilled workforce it needs to drive its EV industry forward—though Ontario workers seeking careers in the province's EV ecosystem will need to develop new skills and competencies in many cases. All stakeholders in Ontario's EV industry and the province's training and education system, including industry, government, post-secondary education instructions, private training organizations, and civil society, have a role to play in upskilling Ontario's emergent EV workforce.

While few EV-specific jobs exist in Ontario today, this can be expected to change quickly as the major EV battery and automotive manufacturing facilities that are currently under construction come online. Likewise, as more Ontarians adopt EVs, there will be a greater need for EV-knowledgeable marketers and salespeople, automotive repair technicians who are skilled at maintaining EVs, and qualified electricians and electrical contractors who can safely install battery charging infrastructure. As the current generation of EVs reaches the end of their lifecycles, a robust EV battery, electronics, and automobile recycling industry can create a circular EV economy in Ontario and throughout Canada.

The role of critical minerals mining and processing has the most uncertain future in Ontario's EV ecosystem. The province has robust mining and minerals processing industries and economically significant quantities of the key critical minerals that are needed in EV batteries and electronic components; however, the remote locations of some critical minerals deposits, the lead time and capital investment required to develop a mine, and the risk associated with new mining ventures could stymie critical minerals development in Ontario in the long run. Such an eventuality would decrease the value captured by Ontario's EV ecosystem, necessitating the out-of-province import of critical minerals to supply the province's EV battery manufacturing facilities. This would be a missed opportunity.

Yet, if Ontario can align all the different industry segments along its domestic EV value chain, including the necessary workforce inputs—while upskilling needed talent and providing pathways to workers interested in becoming involved in the EV ecosystem—the province can develop a robust and globally relevant EV industry.

APPENDIX I: RESEARCH METHODS AND LIMITATIONS

RESEARCH METHODS

ICTC researchers used a mixed methods approach to gather labour market information on Ontario's emerging EV ecosystem and workforce. These primary and secondary research methods are listed below.

SECONDARY RESEARCH

Review of Secondary Literature and Data

ICTC researchers carried out a comprehensive review of publicly available literature and secondary data on EV development and usage in Canada, as well as the automotive manufacturing, mining, automotive sales and distribution, and battery and electronics recycling industries in Ontario. The secondary literature and data helped ICTC researchers map Ontario's EV ecosystem and value chain, develop primary research instruments, including the employer survey, identify employer interview candidates, and validate primary research findings.

EV Ecosystem and Value Chain Mapping

ICTC researchers carried out an iterative process of mapping Ontario's emerging EV ecosystem and derived an EV industry value chain. This ecosystem and value chain mapping exercise primarily involved an analysis of secondary sources on Ontario's preexisting automotive manufacturing and mining, automotive sales and marketing, and battery and electronics recycling industries. ICTC researchers also compared Ontario's emerging EV ecosystem with comparable EV industries in the United States and the European Union. The identified components of the EV supply chain were placed into the upstream, midstream, downstream, and post-stream phases of the value chain. The value chain should be thought of as a high-level representation of Ontario's EV industry and not a detailed diagram of every single step in the manufacturing and lifecycle of an EV.

The resulting value chain map was used by ICTC researchers to develop primary research instruments, identify interview candidates, and structure the final report. The value chain was validated by study participants during interviews and consultations with the project advisory committee.

PRIMARY RESEARCH

Primary research consisted of key informant interviews with employers and experts involved in Ontario's EV ecosystem, an employer survey, a web scrape of EV jobs in Ontario and the United States, and a research advisory committee.

Key Informant Interviews

ICTC researchers carried out a series of confidential and anonymous key informant interviews with 34 employers, experts, and industry representatives throughout the EV ecosystem. Thirty-two of these interviewees were based in Ontario, while two were based elsewhere in Canada. The interviewees represented upstream, midstream, downstream, and post-stream phases of Ontario's EV value chain. Interviews were conducted primarily virtually, though a few interviews were conducted in person or via email. Interviews were carried out by ICTC researchers in a semistructured format and normally lasted 30 to 45 minutes each.

Employer Survey

ICTC contracted a survey firm to produce an employer survey on the automotive sector and the wider EV ecosystem. Survey respondents were recruited from a preexisting industrial panel provided by the survey firm. The survey was carried out between October and December 2023 and was deployed in both French and English. In total, the survey received 155 qualified responses.

In terms of respondent firm size, 46.6% of respondents reported being employed by large firms with 500 or more employees, 17.8% reported being employed by medium-sized firms (200-499 employees), 28.3% by small firms (5-199 employees), and 7.2% by micro-firms (1-4 employees). See Table 14 for a summary.

Table 14: EV/Automotive Employer Survey

FIRM SIZE (NO. OF EMPLOYEES)		NUMBER OF RESPONDENTS	PERCENT TOTAL
Micro	(1-4)	11	7%
Small	(5-199)	43	28%
Medium	(200-499)	27	18%
Large	(500+)	71	47%

Table 14: EV/Automotive Employer Survey, Respondent Firm Size (no. Employees) (n = 152)
Data source: ICTC EV Employer Survey, 2023

Web Scraping

ICTC completed web scraping, an automated process that captures job postings, to identify roles and job titles associated with the upstream, midstream, downstream, and post-stream phases of the EV ecosystem. ICTC scraped popular online job search websites as well as the websites of well-known EV companies. A database of key words was compiled by ICTC researchers and used to identify relevant job postings during the web scrape.

Two web scrapes were conducted: one for EV jobs in the United States from July 2023 to February 2024 and a second for EV jobs in Ontario from September 2023 to February 2024. The web scrape for job postings in the United States was exploratory and was used to better understand the names and key terms used in EV-related job postings. Data collected in the United States web scrape was also used as a comparator and validator for data collected in Ontario. The Ontario web scrape captured job postings throughout Ontario's EV ecosystem. Data collected from the Ontario and United States web scrapes were used to supplement and validate other data used in this report, including common job titles in each phase of the EV value chain. Web scrape data was also used to develop the list of 12 in-demand EV jobs included in Appendix II.

Research Advisory Committee

ICTC hosted a ten-person research advisory committee (AC) of industry representatives and experts. This AC was intended to help ICTC researchers shape their research and assist in validating research findings. During the project, the AC met virtually as a group three times. Individual members of the AC also engaged in one-on-one conversations with ICTC researchers via virtual meetings and email.

LIMITATIONS OF RESEARCH

Ontario's EV industry is rapidly evolving and multifaceted. It can be subject to significant change even over a short period of time. Even a single announcement of a new battery manufacturing facility or automotive assembly plant can have significant implications for the labour market outlook in Ontario. Indeed, during the course of this research study, there were several such announcements in Ontario. Because of the EV industry's rapid development, information, analysis, and conclusions presented in this study risk becoming out of date. The study should be understood as a snapshot in time—a time when the EV industry in Ontario, subject to significant public and private investment, began to coalesce.

By using a mixed methods approach to gathering labour market information, ICTC researchers sought to provide a contextualized assessment of Ontario's emerging EV workforce, segmented by the different portions of the EV value chain. Utilizing data collected from an employer survey, key informant interviews, a web scrape, and secondary data, ICTC researchers explored what demand exists for talent in the EV workforce, what types of talent supplies exist in Ontario, and what gaps the EV industry may face going into the future.

By covering Ontario's entire EV value chain, the study seeks to understand the EV workforce comprehensively. However, by taking this broad approach, the study was unable to investigate in deep detail any of the individual segments of the Ontario EV value chain. For example, a similar study could be carried out on EV battery assembly in Ontario or automotive sales and dealerships alone. Despite sacrificing industry granularity in favour of a broadened sectoral scope, ICTC hopes that this study does justice to the workforce implications and talent needs of each segment of the EV industry in Ontario.

APPENDIX II: IN-DEMAND EV-RELATED JOBS IN ONTARIO

ICTC used job posting data from Canada and the United States to curate a list of 12 in-demand jobs in the EV industry. This list includes jobs in the first three segments of the EV value chain (upstream, midstream, and downstream) as well as a mix of jobs in different occupational fields with varying training and education requirements.

Many of the in-demand jobs pertain to both the EV industry and other related industries. For example, an electrician may participate in the EV value chain by installing home or commercial charging stations in Mississauga but may also carry out other common types of electrical work not tied to EVs. Likewise, a mining engineer may do work to develop a critical mineral mining operation in Northern Ontario, but the resulting minerals may end up supplying both the EV batteries supply chain and the aerospace industry.

Most jobs listed in Table 15 are not exclusively part of the EV industry, as they have relevance to other sectors of the economy. The list is not exhaustive and is intended to be illustrative. The jobs highlighted in the list are also featured as part of ICTC's Skills Mapping Tool.[273]

Table 15: In-demand EV Ecosystem Jobs

EV VALUE CHAIN SEGMENT	ROLE/JOB TITLE	INDUSTRY SEGMENT	ASSOCIATED NOC (2021)
Upstream	Mining Engineer	Mining	21330
Upstream	Mining Geologist	Mining	21102
Midstream	Automotive Battery Manufacturing Chemist	Battery manufacturing	21101
Midstream	Automotive Battery Manufacturing Quality Engineer	Battery manufacturing	21321
Midstream	Automotive Assembly Manufacturing Engineer	Auto manufacturing	21312
Midstream	Automotive Assembly Mechanical Engineer	Auto manufacturing	21321
Midstream	Automotive Assembly Control Engineer	Auto manufacturing	21321
Midstream	Automotive Assembly Production Technician	Auto manufacturing	94200
Midstream	Automotive Assembly Tool and Die Maker	Auto manufacturing	72101
Downstream	Automotive Service Technician/Mechanic	Auto services	72410
Downstream	EV Charging Infrastructure Construction Electrician	Charging infrastructure	72200
Downstream	EV Charging Infrastructure Industrial Electrician	Charging infrastructure	72201

Table 15: In-demand EV Ecosystem Jobs. Data source: ICTC analysis.

273 See: ICTC, Skills Mapping Tool: https://etalentcanada.ca/skills-mapping-tool/selection