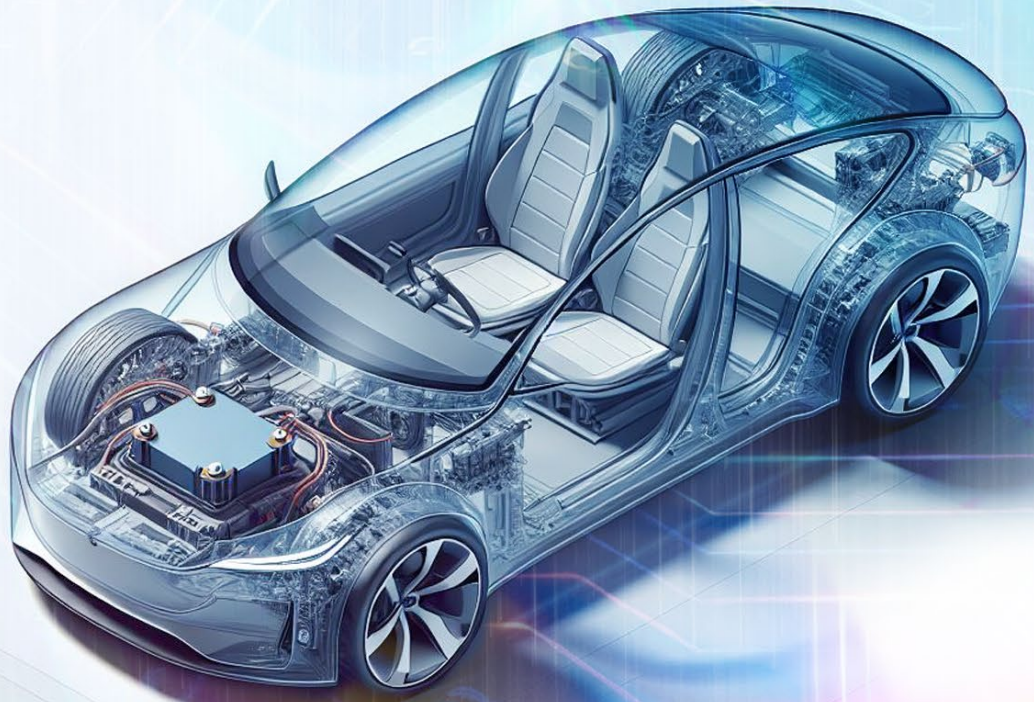
Executive Summary:

Powering the Future

Market Dynamics, Technological Advancements, and the Adoption Trajectory of EV Batteries



Quarterly Specialized Report

December 2024

OVIN AUTONOMOUS · CONNECTED · ELECTRIC Ontario

OVIN INSIGHTS Specialized Series

OCI Where Next Happens

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Executive Summary

Worldwide, the demand for electric vehicle (EV) batteries rapidly increased in recent years as consumers and industries increasingly adopted sustainable transportation solutions. More than one in five cars sold worldwide in 2024 are expected to be electric, and battery manufacturing capacity is expected to exceed 9 terawatt hours (TWh) by 2030, growing from 2.5 TWh in 2023. Growth in the market slowed in 2023 to 40%, down from 65% in 2022, but experts consider this slowdown to be temporary, with the rate of growth anticipated to pick up again from 2029.

In Canada, this trend is boosted by abundant mineral resources, a strong automotive industry, clean energy and water resources, and a robust focus on innovation, establishing the country as a key player in the global EV battery supply chain. By 2030, Canada's EV battery supply chain is projected to reach 160 gigawatt hours (GWh) per year, adding $48B to the economy annually, and supporting between 60K and 250K direct and indirect jobs in Canada, if low-emission vehicle manufacturing and sales target are achieved.

Ontario plays a dominant role in the Canadian automotive landscape – there are five global original equipment manufacturers (OEMs) with manufacturing plants in the province, supplied by an extensive network of nearly 700 parts suppliers. Ontario's ongoing progress in manufacturing and production, coupled with its policy commitments and strong environmental, social, and governance (ESG) credentials, make it an increasingly attractive option for global organizations seeking critical materials and clean energy for manufacturing battery components for the North American market.

Ontario has become a significant hub for EV manufacturing due to its rich reserves of critical minerals and the province's flourishing automotive industry. General Motors (GM) is already manufacturing EVs in the province, and Honda has plans in place to develop a brand-new EV manufacturing plant in Alliston, along with Stellantis, which has announced plans to retool its Windsor and Brampton Assembly Plants for manufacturing EVs. Honda and Toyota are also manufacturing hybrid vehicles in the province.

EV battery manufacturing and battery component manufacturing is on the horizon for Ontario, driven by substantial investments from companies like Honda, PowerCo SE (owned by Volkswagen), and NextStar Energy. Honda's $15B investment will establish a comprehensive EV value chain, including a battery manufacturing facility, battery technology (separator) factory, and a cathode and precursor battery materials processing plant. PowerCo SE and NextStar Energy are also contributing to this growth, with NextStar Energy's partnership between Stellantis and LG Energy Solution already making strides in Windsor. In addition, Magna International and Dongshin Motech have made recent investments to expand their operations in Ontario to include the production of battery enclosures and aluminum casings for EV batteries, respectively. These investments not only enhance Canada's position in the global EV market but also create thousands of jobs and support the country's transition to a sustainable, low-carbon economy.

With the rapid expansion of the EV market, battery recycling and re-use have become crucial components of the EV supply chain. These practices are vital not only for preventing shortages of critical materials but also for reducing the environmental impact of batteries. Ontario's EV battery recycling industry is rapidly expanding, driven by key players like Electra Battery Materials, Glencore Canada, Stelco, and MIRARCO.

As the demand for cleaner energy solutions grows, innovation in battery design is crucial for advancing the efficiency, performance, and sustainability of EVs. Ontario's extensive research and development (R&D) ecosystem plays a pivotal role in this innovation, with several key institutions leading the charge, including the Centre for Hybrid Automotive Research and Green Energy (CHARGE) Lab at the University of Windsor, the FLEX-ION Battery Innovation Center, the National Research Council (NRC) Battery Performance and Safety Evaluation Research Facility, the Ontario Battery and Electrochemistry Research Centre (OBEC) at the University of Waterloo, and the UTEV Research Centre at the University of Toronto.

This report delves into the latest technologies and trends shaping the industry, providing a comprehensive overview of the EV battery market landscape globally and within Canada. It explores the future market outlook, highlighting Ontario's skilled workforce and the provincial initiatives spearheaded by the Ontario Vehicle Innovation Network (OVIN). Additionally, the report examines the impact of other industries on the EV battery sector and maps out Ontario's robust ecosystem, featuring key players in R&D, manufacturing, and recycling.

Drawing on insights from experts both globally and locally, the report offers strategic recommendations to ensure Ontario's continued leadership in the EV battery industry.

Experts provide a nuanced outlook on the EV battery industry, emphasizing several key factors that will shape its future. They consider the current market slowdown to be a temporary phase projecting that from 2030 to 2035, the growth rate in EV battery manufacturing plants (also referred to as gigafactory) capacity will need to rebound to around 20% per year to meet increasing demand. Access to venture capital is highlighted as a critical driver for the industry's growth, particularly in regions like Ontario. Additionally, ongoing advancements in battery technology are crucial for the initial setup of gigafactories, which should be designed modularly to accommodate continuous production and regular innovations. Experts also note that the chemistry of EV batteries is likely to evolve, potentially moving away from lithium-based technologies. This evolution will necessitate adaptations in recycling methods to ensure effective material recovery and sustainability. These insights collectively underscore the dynamic and evolving nature of the EV battery industry, pointing to both challenges and opportunities ahead.

"Having attracted $45B in new electric vehicle and EV battery investments over the last four years, our government is delivering on a plan to build a fully integrated end-to-end EV supply chain in Ontario."

- The Honourable Victor Fedeli, Ontario Minister of Economic Development, Job Creation and Trade

1. Significance of EV Batteries

The global significance of EV batteries cannot be overstated. As the world transitions towards cleaner and more sustainable energy solutions, EV batteries have emerged as a cornerstone of this transformation.

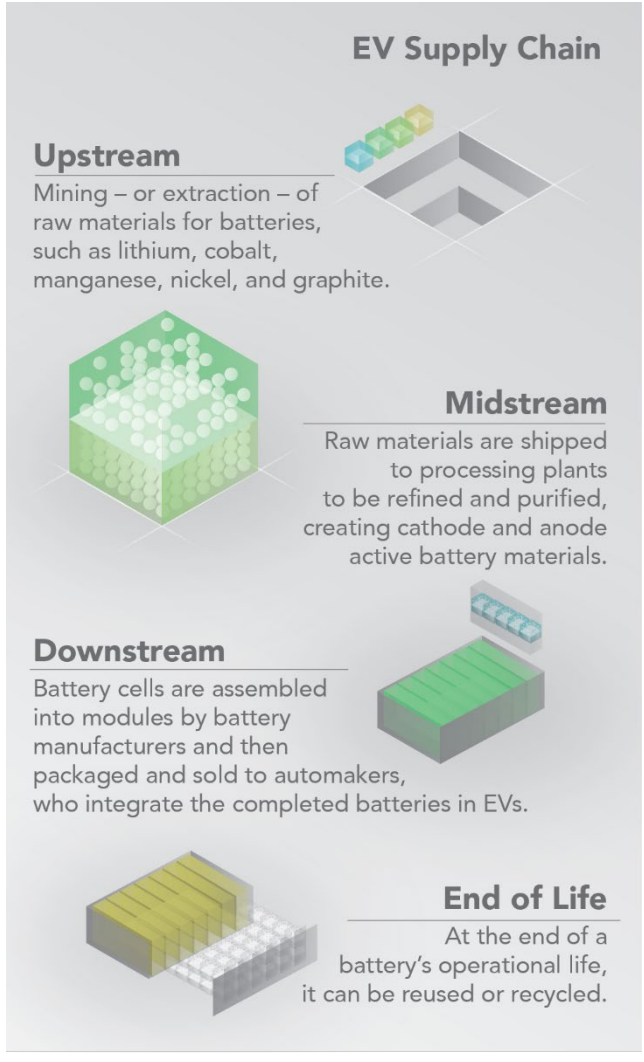
1.1 Global and Local Focus

Growth in EV sales is driving the demand for batteries, with more than one in five cars sold worldwide in 2024 expected to be electric. In 2023, demand for EV batteries reached over 750 GWh. As uptake shifts from early adopters to the mass market the pace of growth is expected to slow, but sales data remains strong – global EV sales grew by around 25% in the first quarter of 2024 compared with the first quarter of 2023.

1.2 The EV Battery Supply Chain

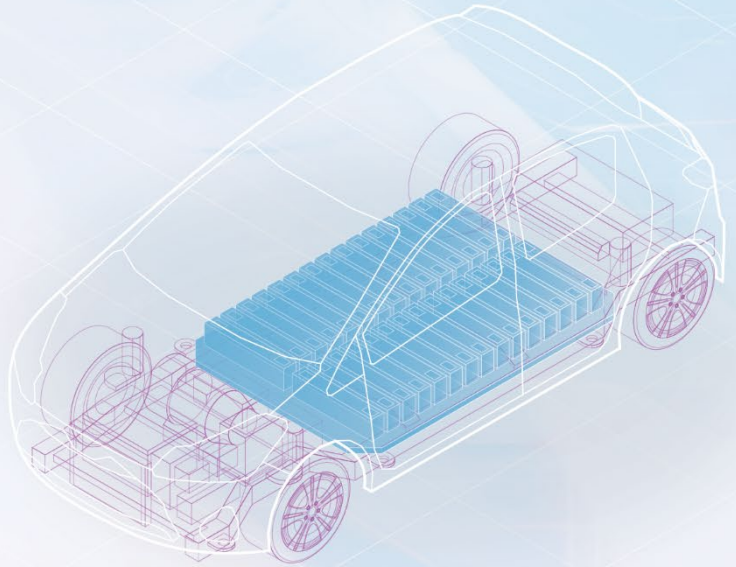
There are four core steps in the EV battery supply chain: Upstream, Midstream, Downstream, and End of Life. Upstream refers to the mining of critical raw materials required for battery components. Midstream refers to the transportation of these raw materials to processing plants to be refined, purified, and transformed into cathode and anode active battery materials. This is followed by Downstream, where battery cells are assembled into modules by battery manufacturers and packaged and sold to automakers. The automakers then integrate the completed batteries into EVs. The final stage is End of Life, which consists of either the reuse or recycling of the batteries.

The supply chain for EV batteries is complex, with materials typically travelling more than 50K miles before reaching downstream battery cell manufacturers. Upstream raw material supply is chiefly located in a few countries, causing vulnerabilities in the EV battery supply chain and making it susceptible to disruptions such as geopolitics and changing trade alliances. Resulting in negative impacts in the supply chain, leading to delays and increased transportation costs, discouraging investment, and impeding transportation decarbonization targets. The midstream stage also faces several challenges. As there is a limited number of facilities concentrated in a few countries which are capable of refining critical minerals. This bottleneck can lead to supply shortages and increased costs. China typically dominates in this space, with over half of global lithium, cobalt and graphite processing and refining capacity located there. Additionally, producing high-quality battery materials requires advanced technology and stringent quality control. Any lapses can lead to inefficiencies and lower performance of the final batteries. It is therefore important to develop a supply chain which is secure, reliable, and sustainable.

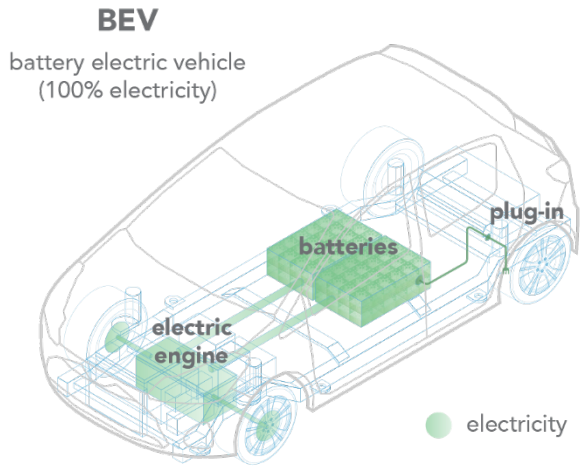


2. Battery Technologies and Trends

Battery technologies are central in the transition to sustainable transportation, enabling the widespread adoption of EVs. As the demand for cleaner energy solutions grows, innovations in battery design – such as solid-state and silicon anode technologies – are emerging to enhance energy density, reduce costs, and minimize environmental impact. The evolution of EV battery technologies not only drives the automotive industry forward but also contributes significantly to reducing greenhouse gas emissions and combating climate change.

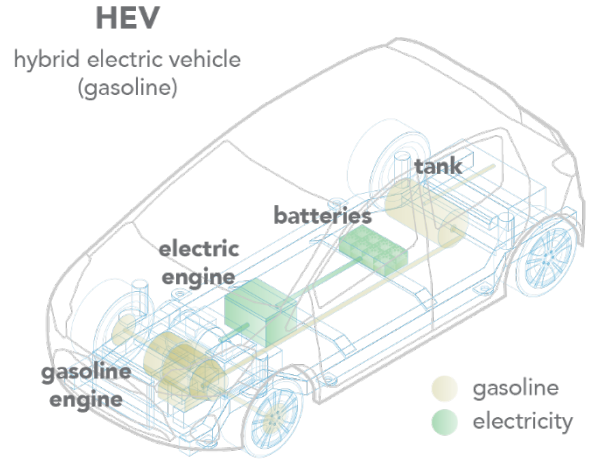


2.1 Different Types of EV



Battery Electric Vehicle (BEV)

BEVs are powered entirely by electricity, featuring larger batteries than hybrid vehicles, which allows them to produce zero emissions and operate quietly without engine noise, making them the most environmentally friendly option among EVs. However, they do have some disadvantages, such as a limited driving range compared to hybrids – as they rely solely on battery power – and longer charging times, which can be inconvenient for long-distance travel.

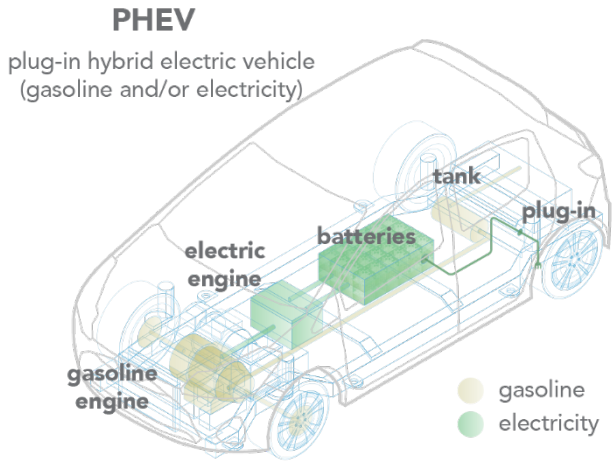


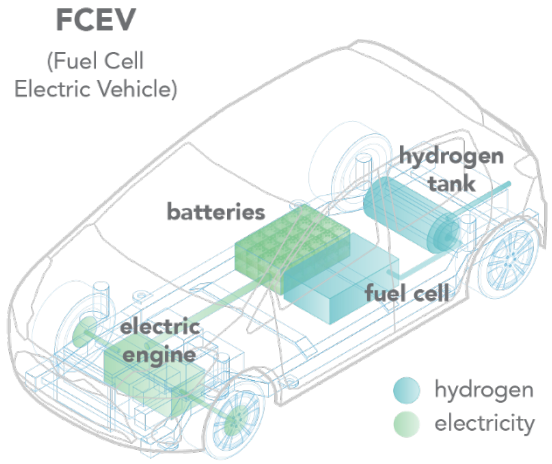
Hybrid Electric Vehicle (HEV)

HEVs combine a combustion engine with a smaller electric battery, utilizing both power sources to extend driving range, as the engine assists the electric motor. They recharge their batteries through regenerative braking rather than requiring a plug-in, making them convenient for long trips without charging stops. However, HEVs are not as environmentally friendly as BEVs since they still emit pollutants, and while they tend to be more affordable than BEVs, they can be pricier than traditional gasoline vehicles.

"Canada is one of the few countries in the world that has everything it needs to be a global leader in EV and battery manufacturing: talent, green energy, and critical minerals"

- The Honorable François-Philippe Champagne, Minister of Innovation, Science and Industry





Plug-In Hybrid Electric Vehicle (PHEV)

PHEVs combine a larger battery with a combustion engine, similar to HEVs, but they allow for external charging. A key advantage is their extended electric range, allowing for longer trips on a full charge, and they emit fewer pollutants on average than HEVs, especially during shorter trips when operating in electric mode. However, PHEVs usually have a higher initial cost than HEVs, but are generally less expensive than BEVs. While they can run on gasoline, regular charging is crucial for optimal performance.

Fuel Cell Electric Vehicles (FCEVs)

FCEVs generate electricity on-board via chemical reaction in a hydrogen fuel cell, emitting only water vapor as a byproduct. They offer advantages like quick refueling times at specialized hydrogen stations, and an impressive driving range, making them suitable for large vehicles and long-distance travel. However, challenges include the unevenly distributed hydrogen refueling infrastructure and varying environmental impacts based on the hydrogen production method, such as natural gas reforming versus renewable energy electrolysis.

“By lowering the cost of doing business in the province by $8B a year, we’re showing the world that Ontario is a top jurisdiction for multinational manufacturers to invest and expand their operations.”

- The Honourable Victor Fedeli, Ontario Minister of Economic Development, Job Creation and Trade

2.2 Current Battery Technologies

EV batteries predominantly use lithium-ion technology, which has become the industry standard due to its high energy density and relatively low weight. A small selection of other battery types, such as nickel-metal hydride and lead-acid batteries, are used for hybrid vehicles and auxiliary applications.

Lithium-Ion Batteries

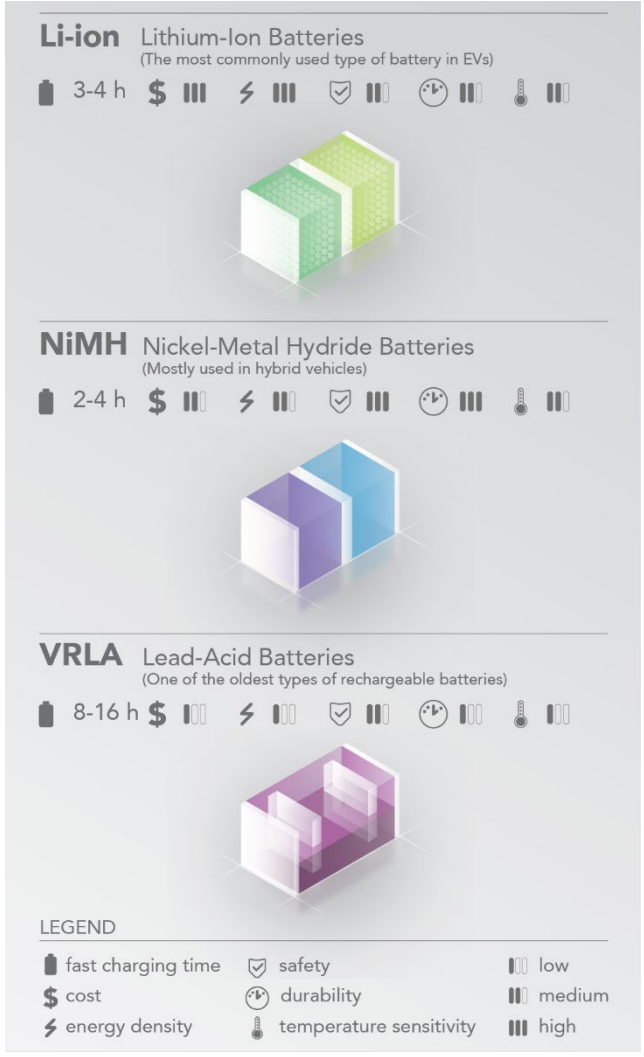
The most commonly used type of battery in EVs, lithium-ion (Li-ion) batteries use lithium compounds in their electrodes and can store a large amount of energy in a relatively small package. There are a range of Li-ion batteries available, such as nickel manganese cobalt (NMC), nickel cobalt aluminum (NCA), and lithium iron phosphate (LFP). Li-ion batteries have a relatively long operational life span, can provide the high energy needed for long driving ranges, and are lightweight, making them the preferred choice for EVs. However, they are expensive to produce, require complex battery management systems, and have a risk of overheating.

Nickel-Metal Hydride Batteries

Mostly used in hybrid vehicles, nickel-metal hydride batteries (NiMH) are comprised of a nickel-hydroxide positive electrode, a hydrogen-absorbing alloy negative electrode, and a potassium hydroxide electrolyte. These batteries are durable and relatively low cost when compared to other battery types, with a long lifecycle. They are not as energy dense as Li-ion batteries but are considered to be more environmentally friendly due to the use of non-toxic materials.

Lead-Acid Batteries

One of the oldest types of rechargeable batteries, valve-regulated lead-acid (VRLA) batteries are used in a wide range of applications, including automotive, backup power, and low-speed EVs. Lead-acid batteries are comprised of lead dioxide and lead plates submerged in a sulfuric acid electrolyte. These batteries are reliable and low cost but have a low energy density and are heavy weight, resulting in them typically no longer being used as the primary power source for EVs, instead being used in auxiliary applications such as power steering, brake boosting, and radio and sound systems.



2.3 State-of-the-Art Technologies

The ongoing need for more efficient, longer lasting batteries to maintain the demand for EVs has resulted in a surge in research and innovation to identify advancements in battery technology. A selection of state-of-the-art technologies currently undergoing development are outlined below.

Solid-State Batteries use solid electrolytes rather than liquid or gel, like traditional batteries. This emerging technology offers increased energy density and range, faster charging, improved safety through reduced risk of fire, longer lifespan, and a lighter weight resulting in more efficient vehicles. Still in the development phase, projections estimate that solid-state batteries could reach a full charge in around 10 to 15 minutes and have a range of 600 miles. Honda has recently announced a demonstration production line for solid-state batteries in Japan, with battery production anticipated to begin in January 2025. Toyota has also recently announced plans to launch a passenger vehicle powered by solid-state batteries, with production expected to begin in 2026.

Cobalt-Free Batteries are a type of Li-ion battery which avoid the use of cobalt as a cathode, instead using nickel, aluminum, and manganese. Cobalt is harmful to extract due to health risks for miners and damaging environmental impacts. It is also expensive, rare, and has been linked to unethical mining practices in countries such as the Democratic Republic of the Congo. The University of Toronto has undertaken research into cobalt-free technologies, finding that these types of batteries can meet the demanding energy density required for EVs. Additionally, Massachusetts Institute of Technology (MIT) researchers have developed a new battery material which is based on organic compounds, instead of cobalt. This material offers comparable performance and could be produced at a lower cost.

Graphene-Based Batteries use a compound of graphene and other materials in lithium-sulfur cell cathodes. This technology presents

opportunities for higher energy densities, increased life span, and fast charging. Graphene batteries are expected to emerge as the main contender for EV battery technologies – challenging Li-ion technology – in the early to mid-2030s due to falling production costs. The Chinese automobile company GAC Motor Co. Ltd has announced the launch of a vehicle featuring a graphene battery which has a range of 1K kilometers.

Silicon Anode Batteries replace the graphite in Li-ion battery anodes with silicon, which has 10 times the capacity. Researchers at the University of Waterloo have been at the forefront of silicon anode battery technology since 2015. Additionally, the University of Eastern Finland has developed a new environmentally friendly hybrid material which uses mesoporous silicon microparticles, produced from barley husk ash, and carbon nanotubes to improve performance. Moreover, GM has partnered with OneD Battery Sciences – a California-based nanotechnology firm – to explore the use of silicon anode technology in its battery cells.

Zinc-Air Batteries are comprised of a zinc negative electrode and an air positive electrode. Cheaper to produce than Li-ion batteries due to a global abundance of zinc, they are safer, more environmentally friendly, and can store more energy. However, there have been limitations in relation to their ability to recharge, limited power output, and short lifespan. Recent advancements by the University of Sydney and Edith Cowan University in Australia have improved recharge rates, increased voltage, and improved stability. In 2022, Toronto-based zinc-air battery company e-Zinc and Toyota Tsusho (a member of the Toyota Group) signed a pilot project agreement to test eZinc's zinc-air battery storage systems.

Nanowire Batteries use highly conductive nanowire-based electrodes thousands of times thinner than human hair. Until recently, batteries using this technology were considered unfeasible due to the extremely fragile filaments. Recent advancements at the University of California use gold nanowires encased in a manganese dioxide shell, covered in an electrolyte of gel. This new technique resulted in nanowire batteries which can be recharged hundreds of thousands of times, without any degradation of capacity or power.

Structural Battery Packs offer a new technology which can both store energy and provide structural support for EVs. This enables redundant structural elements to be removed from the vehicle, making it more light weight, and therefore increasing efficiency and range. They are estimated to increase the driving range of EVs by up to 70%. Researchers at Chalmers University of Technology in Sweden have recently developed structural battery technology which uses carbon fiber working simultaneously as an electrode, conductor, and load-bearing material.

Carbon Nanotube Electrodes offer the potential for improved performance, increased battery storage, and reduced charging time compared to standard battery technology. Carbon is a highly conductive material which can be used in both the cathode and anode and remains stable at high temperatures. Nawa Technologies has designed and patented an Ultra Fast Carbon Electrode which it claims can increase battery power by 10 times more than current battery packs, increase energy storage by a factor of three, and increase the battery lifecycle by five times.

Hydrogen Fuel Cell vehicles offer an alternative to battery powered EVs, instead using electricity produced by hydrogen to power an electric motor. For automotive applications, the most widely used type of fuel cell is that of the polymer electrolyte membrane (PEM) fuel cell, which comprises of an electrolyte membrane contained between a cathode and an anode. These vehicles are fueled by pure hydrogen gas which is stored in a tank on the vehicle. Hydrogen is introduced to the anode and oxygen to the cathode, causing an electrochemical reaction. Hydrogen fuel cell vehicles are also equipped with regenerative braking systems which capture energy lost during braking and store it in a battery. They have a driving range of over 300 miles.

2.4 End-of-Life Approach

Following the rapid growth of the EV market, battery recycling and re-use are increasingly important steps in the EV supply chain.

2.4.1 Battery Recycling Technologies

Battery recycling is an emerging market globally, with technologies and processes undergoing constant development. There are a number of processes which can be used to recover and separate materials in Li-ion batteries. These include:

Pyrometallurgy – also known as smelting, this method involves using high temperatures to facilitate oxidation and reduction reactions, enabling metals such as cobalt and nickel to be recovered in a mixed metal alloy, which can then be separated by hydrometallurgy. Other materials in the battery, such as the aluminum, anode, and electrolyte, supply much of the energy for the process through being oxidized in the smelter.

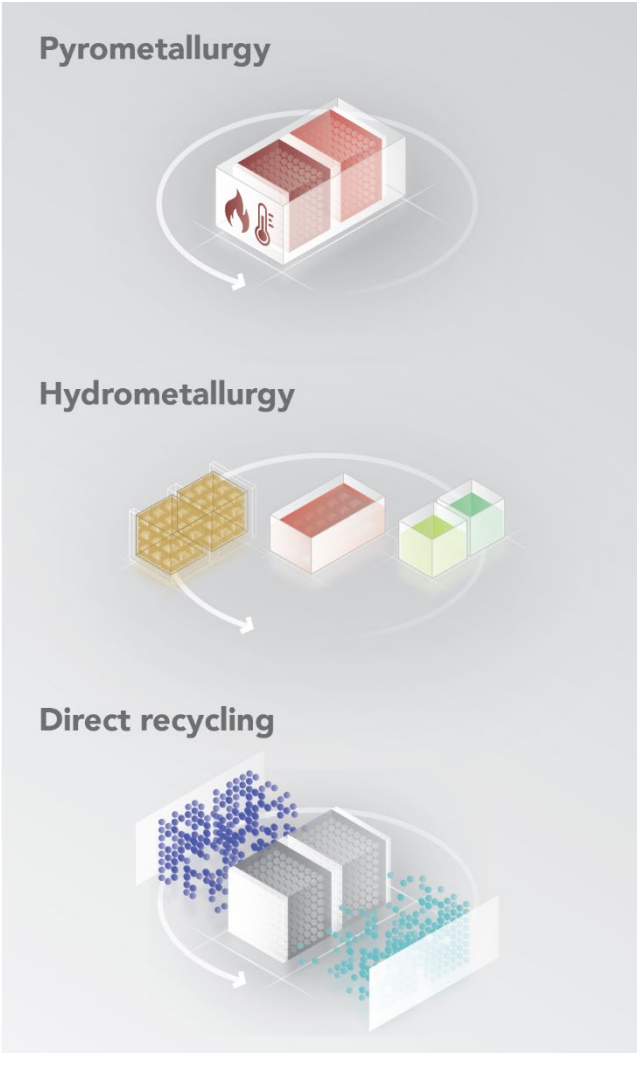
Hydrometallurgy – this method begins with dismantling or shredding the cells (resulting in an active material powder referred to as black mass), and then leaching in acids to dissolve ions out of a solid, producing a mixture of atoms and molecules which can be recovered by precipitation or solvent extraction. Reactions with other recovered materials enables a new cathode material to be produced.

Direct recycling – this method also starts with dismantling or shredding the cells to produce black mass. The different components of the black mass are separated by physical processes, such as gravity separation, meaning that all active materials and valuable metals can be recovered without chemical changes. This can result in not only higher recovery rates, but also lower energy consumption, reduced environmental impact, and recovery of better-quality materials.

2.4.2 Emerging Battery Recycling Technologies

A number of potential areas for innovation in battery recycling have been identified in recent years. These include the following:

Graphite recycling – currently treated as a by-product which is burnt for energy or sent to landfill, there is significant potential for used graphite to be recycled as a battery-grade product.



Adding fluorine into graphite recycling has been shown to slow down chemical reactions and battery degradation and may therefore improve battery performance.

Electrolyte recovery – electrolyte is highly volatile, toxic, and flammable and as such has a complex removal process. However, it contains a concentration of lithium salts and organic solvents which are considered valuable for recovery. Research is currently underway to establish an efficient recovery method, with options including pyrolysis (thermal decomposition of materials at high temperatures under inert environment), organic solvent extraction, supercritical extraction (using fluid above the critical temperature and pressure), alkaline absorption, vacuum distillation, freezing, and mechanical separation.

Lithium extraction – new techniques are currently undergoing development for more environmentally friendly and efficient methods of lithium extraction. One such recent innovation is the use of microwave radiation and a readily biodegradable solvent.

2.4.3 Battery Recycling Trends

Governments around the world are taking steps to advance EV battery recycling capabilities and capacity via technological advancements, regulatory support and policies, and circular economy initiatives. However, experts note that the future trend of EV battery recycling hinges on the increasing number of EVs on the road and the eventual operational end-of-life of their batteries. This point is still quite far off, as many EV batteries are expected to last at least 10 to 12 years, with some potentially reaching up to 20 years, especially in well-maintained vehicles that are not heavily used.[1] As these batteries reach the end of their lifecycle, the industry will need to develop efficient recycling processes to handle the growing volume, ensuring sustainable management of battery materials and reducing environmental impact.

2.4.4 Battery Re-Use

An alternative approach for a more sustainable supply chain is battery re-use. When batteries reach the end of their operational life for application within an EV, they still typically retain 70-80% storage capacity and so can be re-used in static storage applications, where weight and space are less critical. Examples include energy storage systems for renewable energy technologies, helping to ease pressure on the power grid.

2.5 Future Trends

Demand for EV batteries is expected to grow over the next decade, with the International Energy Agency (IEA) estimating that demand could grow between seven and 12 times by 2035, compared to 2023.

BloombergNEF predicts that battery technologies will continue to improve and get cheaper in the coming years, resulting in many new, lower-cost EV models launching. This is expected to lead to the fastest growth rates in emerging economies.

If current battery manufactuing investments are completed in full and on time, the IEA predicts that capacity could exceed 9 TWh by 2030. This growth in demand will help to foster an emerging battery recycling industry as EV stock ages and requires effective, sustainable end-of-life strategies. The IEA estimates that global battery recycling capacity could exceed 1.5K GWh in 2030.

MIRARCO: A Success Story in EV Battery Recycling

MIRARCO (Mining Innovation Rehabilitation and Applied Research Corporation), based in Sudbury, Ontario, is renowned for its research and development in mining and environmental sustainability. With the increasing demand for critical minerals like nickel, cobalt, and copper, essential for EV batteries, MIRARCO has focused on developing technologies to recover these metals from mine tailings.

In June 2024, MIRARCO received a $5M grant from Natural Resources Canada. This funding was aimed at enhancing the technological readiness for extracting battery metals from mine tailings in the Greater Sudbury area. This grant underscores the Canadian government's commitment to supporting sustainable mining and the critical minerals sector and is one of MIRARCO's key projects.

The approach to reprocessing mine tailings to extract valuable minerals addresses the challenge of insufficient new ore production to meet the growing demand for EVs. By developing and scaling the necessary technology, MIRARCO aims to tap into the mineral wealth already present in surface mine tailings. A key challenge for the organization is in developing and scaling the technology.[2]

Through the Center for Mine Waste Biotechnology, MIRARCO's vision is to develop critical mineral streams from existing waste materials using low-carbon biotechnologies. This long-term goal has already attracted interest from battery companies looking to improve their material supply chains. Although MIRARCO's primary focus was not initially on this area, they now see themselves playing a significant role in the midstream sector. Despite their history in hard rock underground mining, they continue to collaborate with mining companies in the upstream space. The main challenge across all stages remains innovation, and MIRARCO aims to bring together academic institutions and private sector researchers to address these challenges, with a primary focus on tailings and waste reprocessing.[3]

MIRARCO's success in EV battery recycling has far-reaching implications. Their work not only supports the EV industry by providing a steady supply of critical minerals but also promotes environmental sustainability. The technologies developed by MIRARCO can be scaled and implemented in other regions, potentially revolutionizing the way we approach battery recycling and resource recovery.

This Success Story was written with contributions from Nadia Mykytczuk, President and CEO of MIRARCO.

3. The EV Battery Market Landscape

Globally, the demand for EV batteries is surging as more consumers and industries shift towards sustainable transportation solutions. In Canada, the landscape is further strengthened by rich mineral resources and a strong commitment to innovation, positioning the country as a significant contributor to the global EV battery supply chain.

3.1 Driving Factors

The growth of the EV battery market is being driven by a number of aspects, including government policies and incentives, consumer demand, technological advancements, environmental concerns, economic factors, infrastructure development, and supply chain challenges.

In 2023, the global EV battery market was valued at USD $59.06B and is anticipated to grow with a compound annual growth rate (CAGR) of 6.4% to USD $111.2B by 2032. In support of this expected growth, jurisdictions around the world are taking steps to strengthen their EV battery supply chains, with competition between regions being a major driving factor of the battery industry. Currently three major blocs – Europe, North America, and China – are vying for dominance.[4] Initiatives such as the United States' Inflation Reduction Act, and the EU's new Batteries Regulation have been introduced to ensure competitiveness in the global market.[5] China continues to be a formidable player with its own advancements and strategies. This intense competition is fostering innovation and accelerating the development of the EV battery sector globally.

Consumer demand for EVs continues to grow as there is an increasing awareness of climate change and the need to reduce greenhouse gases. EV batteries play a critical role in this. Concurrently to this, ongoing advancements in battery technologies, such as increased range, faster charging times, and longer battery life, help to make EVs more attractive to consumers.

Supply chain challenges are also a key driving factor of the EV battery market. EV batteries rely heavily on critical minerals such as lithium, cobalt, nickel, manganese, and graphite. The high demand for these minerals has led to significant investments in mining and refining worldwide, but supply chain bottlenecks and geopolitical factors can impact the availability and cost of these minerals. In 2023 the price of all key battery metals fell, resulting in a nearly 14% reduction in battery pack price between 2022 and 2023. This decline in battery costs will in turn make EVs more affordable, helping to steer consumer demand.

3.2 Global EV Battery Policy Landscape

In 2023, the EU introduced the European Green Deal. This set of policy initiatives aims to put the EU on the path to a green transition, becoming climate neutral by 2050. One aspect of this is the Green Deal Industrial Plan which sets out provisions to scale up the EU's manufacturing capacity for net-zero technologies, including the production of EV batteries. It also introduced a Critical Raw Materials Act, ensuring access to the materials required for manufacturing key technologies, and commits to developing the EU's network of free trade agreements. Another initiative introduced via the European Green Deal is the EU Batteries Regulation, which aims to ensure that batteries on the EU market are sustainable and circular throughout their entire life cycle. It also introduces the requirement for 'battery passports', which will enable the transfer of key information between parties via a digital record system, ensuring that batteries entering the EU market have passed certain environmental regulations.

In 2022, the United States government introduced the Inflation Reduction Act, which focuses on improving clean energy manufacturing and recycling, industrial decarbonization, critical materials processing, refining, and recycling, incentivizing domestic production, improving supply chains, and electrifying heavy-duty vehicles. Experts have cited this Act as being the

most important legislation for the EV battery sector.[6] Specifically, the Act encourages increased uptake of EVs via the Clean Vehicle Tax Credit (Section 30D), aims to fortify the domestic EV supply chain by stipulating that critical minerals should be extracted or processed in the United States or a Free Trade Agreement country, or be recycled and assembled in North America, and expands the Advanced Technology Vehicles Manufacturing Direct Loan Program. Also, the Advanced Manufacturing Production Tax Credit (Section 45X) and Advanced Energy Project Investment Tax Credit (Section 48C) can support Li-ion battery manufacturing and recycling. Section 45X may be more important than Section 30D.[7] Experts note that the expansion of the Direct Loan Program allows substantial loans to be provided to projects, particularly those related to Li-ion gigafactories in the United States. These loans, which typically range from USD $100M to USD $1B, come with low interest rates and a high tolerance for particular types of risk (e.g. technology and offtake). This financial support is a major factor driving the growth and activity in the United States EV battery industry.[8]

In 2024, the Australian government launched a National Battery Strategy which sets out how the country can establish and sustain a domestic battery industry. The strategy includes the following initiatives and investments:

- Battery Breakthrough initiative to promote the development of battery manufacturing capabilities via production incentives (AUD $523.2M).
- Building Future Battery Capabilities initiative to enhance collaboration between industry and research (AUD $20.3M).
- Delivery of the Australian Made Battery Precinct (AUD $5.6M).

Furthermore, China has offered financial subsidies for EV consumers since 2009, reaching a total of USD $28B by 2022, when these subsidies were phased out. The Chinese government now offers tax incentives to consumers via its New Energy Vehicles Tax Reduction and Exemption Policy. This policy aims to promote the adoption of EVs by exempting purchase tax on qualifying vehicles and has recently been extended to 2027. In addition, automakers are exempt from consumption tax and vehicle and vessel tax for the production, subcontracted processing, and importation of EVs.

Another country taking steps to create a sustainable battery industry is Norway. The Norwegian government launched the country's first battery strategy in 2022, outlining 10 measures to develop a coherent and profitable battery value chain. This strategy aims to position Norway as a leader in sustainable battery production. In addition, the government has approved approximately $14.6M to support a research project focused on establishing sustainable battery production in the country.

Japan has also implemented several measures to support the development of its EV battery supply chain. The Japanese government has a battery strategy which aims to build out 150 GWh per year of domestic battery production capacity by 2030. As part of this, Japan has committed up to USD $2.4B in subsidies to support EV battery manufacturing projects by major automakers like Toyota, Nissan, Subaru, and Mazda. This funding aims to enhance domestic battery production capabilities and reduce reliance on foreign suppliers.

Finally, South Korea has also committed to fostering a domestic EV battery supply chain. The government is committing over USD $28.8B in financial support over the next five years to

enhance its rechargeable battery industry. This includes boosting reserves of critical minerals like lithium and cobalt, nurturing the battery recycling ecosystem, and reducing reliance on foreign suppliers. The government will provide cheap loans, insurance benefits, and tax credits for overseas resource development.

3.3 Canada's EV Battery Landscape

The Canadian government has laid the foundation for the country's EV and battery market through a mandatory target of 100% of new light-duty car and passenger truck sales to be zero-emission by 2035. In addition, the federal government has introduced the Incentives for Zero-Emission Vehicles (iZEV) Program, and the Zero Emission Vehicle Infrastructure Program (ZEVIP). The federal government also introduced the Clean Technology Manufacturing Investment Tax Credit in 2023, which is a refundable tax credit aiming to encourage capital investment for clean technology manufacturing, including EVs and batteries, and the extraction and processing of critical minerals.

Canada has recently been identified by BloombergNEF as the top country in the world for its potential to build a secure, reliable, and sustainable Li-ion battery supply chain. There are a number of factors which contribute to the strength of Canada's supply chain and market landscape. Canada has an abundance of raw materials, and the critical minerals required to manufacture EV batteries. These materials are available at the scale required for a robust supply chain, along with a well-established mining sector, and 50 smelters or refineries to enable sustainable production of battery-grade materials. Furthermore, the Canadian supply chain of raw and critical materials offers shorter, more traceable routes to markets than those sourced internationally. The federal government launched the Canadian Critical Minerals Strategy in 2022, which sets out a course for the country to become the global supplier of choice for responsibly sourced critical minerals. The country has also seen an influx of substantial investments related to the EV battery supply chain in recent years.

Canada has a well-established automotive ecosystem and is one of the world's top 12 producers of light vehicles. There are five global OEMs with manufacturing plants in Ontario, supplied by an extensive network of nearly 700 parts suppliers. In addition, Canada has strong links with the automotive market in the United States, solidified by the first United States – Canada EV corridor being announced in 2023, stretching from Kalamazoo, Michigan to Quebec City, Quebec. This announcement strengthens the ongoing collaboration between the two nations, supporting continued growth in EV jobs, manufacturing, and supply chains. Furthermore, Canada has access to 15 free trade agreements with 51 countries, including the United States-Mexico-Canada Agreement, and is a tariff-free zone for manufacturers.

In addition, Canada has several working groups and associations dedicated to the development and advancement of EV batteries. These include the Battery Metals Association of Canada, which aims to grow the battery industry in Canada and expand the domestic supply chain, the Canadian Battery Task Force – developed as part of Accelerate, Canada's zero emission vehicle industrial alliance working towards building the EV supply chain – which is an industry-led coalition created to advance Canada's domestic battery industry, and Electric Mobility Canada, which is working to advance the transition to electric mobility.

3.4 Recent Fluctuations in Demand

The global EV battery market experienced rapid growth in recent years, with EV sales increasing exponentially year on year by around 20%,[9] and demand for automotive Li-ion batteries reaching a peak of 65%, at 550 GWh, in 2022. As a result of this accelerated growth, there was a ramp up of investment in battery gigafactories around the world.[10] Growth in the market slowed in 2023, at 40% relative to 2022. This slowdown is due to weak demand from consumers, with a number of factors contributing to this. These factors include the lack of charging infrastructure contributing to range anxiety, long charging times affecting perceptions of convenience, and the initial cost of EV acquisition making ownership inaccessible for many. Broader impacts include disruptions to the supply chain, market saturation, and global economic conditions such as inflation and recession fears.

In response to the recent downturn in demand, OEMs and battery manufacturers around the world have curtailed previously announced investments, with many battery gigafactories being postponed or scaled back. These announcements may, in the long run, be a smart decision as it will allow more time for technological advancements and supply chain development as consumers' willingness to shift increases.

Experts consider the market slowdown of 10% per year in 2024 to be temporary, estimating that in the medium to long term (2030 to 2035) the rate of growth in gigafactory capacity will have to return to around 20% per year to meet demand.[11] This will in part be driven by legislation from governments around the world stipulating that automakers must become emission free in the coming years.[12]

3.5 Future Market Outlook

Despite EV battery market forecasts predicted to be lower than previously expected in 2025, at 22.6%, and 2028, at 35%, the market is expected to continue growing, albeit at a slightly reduced pace than during its initial early-years boom. The market is predicted to pick up again from 2029.

By 2050, under BloombergNEF's Net Zero Scenario, the global EV market is projected to reach USD $98T. This is estimated to comprise of 74% passenger EVs, 20% commercial EVs and e-buses, and 6% electric two- and three-wheelers.

In Canada, the EV battery supply chain has been estimated to add $48B to the economy annually by 2030.

Battery manufacturing capacity is expected to continue to grow. In 2023, battery manufacturing capacity reached 2.5 TWh. The IEA predicts that this could exceed 9 TWh by 2030, of which approximately 70% is already operational or otherwise committed.

"Over the last four years, Ontario has become the epicentre of Canada's EV supply chain, attracting billions in investment by global automakers and suppliers of batteries and battery materials"

- The Honourable Victor Fedeli, Ontario Minister of Economic Development, Job Creation and Trade

4. Ontario’s EV Battery Talent Landscape

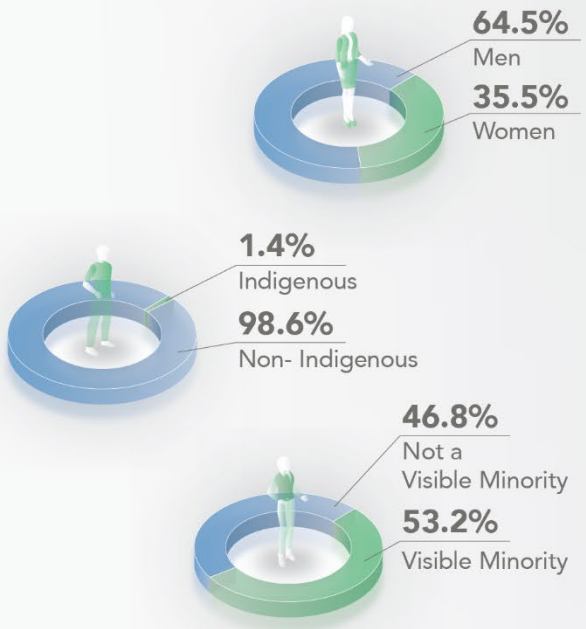
The EV battery industry in Ontario is rapidly evolving. As the EV battery sector grows, so does the need for a skilled workforce capable of meeting the challenges and opportunities presented by this dynamic field. Battery manufacturing today is highly automated. Unlike the past, where cars were assembled by labourers on production lines, modern battery factories employ highly skilled professionals such as chemists, software engineers, and automation engineers. This shift requires a different skill set compared to previous generations of manufacturing. When deciding on the location for a gigafactory, the availability of a skilled workforce is a crucial factor, alongside considerations like the regional supply chain and access to low cost and renewable energy.[13]

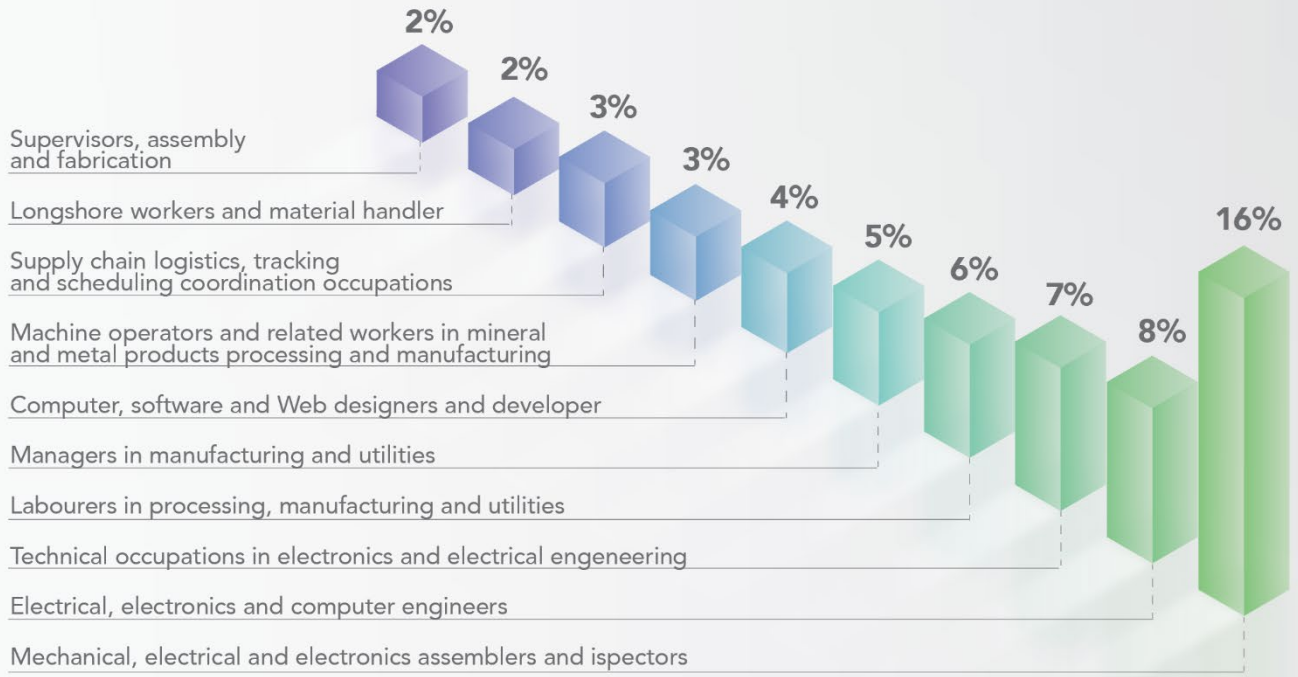
4.1 Labour Market Status

13,480
workers employed in industries related to battery manufacturing in Ontario in 2021.

Equity, Diversity,and Inclusion

representation in Ontario's semiconductor, electrical equipment, and related components industries in 2021.





Top 10

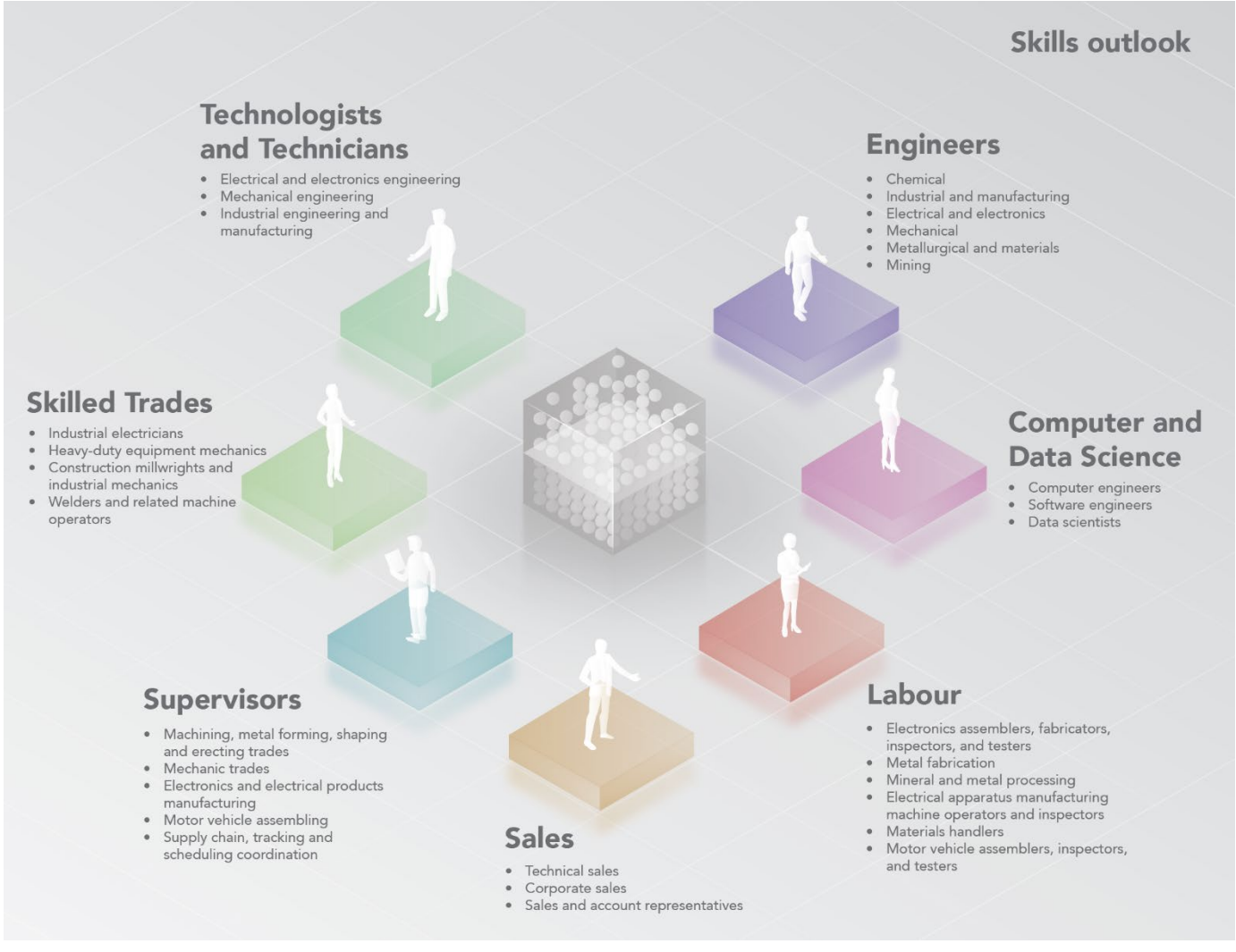
Occupations based on employment in semiconductor, electrical equipment, and related components industries, which encompass activities relevant to battery manufacturing (NAICS 3359 and 3344).

4.2 Skills Outlook

The EV battery supply chain is predicted to support between 60K and 250K direct and indirect jobs in Canada by 2030. With this in mind, up to 2032, labour market gaps are predicted to be high – i.e. projected total demand for workers exceeds availability of workers in the labour market – for manufacturing competencies, and this is therefore a high priority for talent acquisition. Areas with a low labour market gap, and therefore of a lower priority, include managerial occupations and certain trades, such as power engineers and power systems operators.

Over the next 10 years, the highest skills gaps are anticipated to be related to Enterprise Resource Planning (ERP) systems, Supervisory Control and Data Acquisition (SCADA) systems, 3D Computer Aided Design (CAD) software, and Materials Requirement Planning (MRP) software.

Expected labour market requirements critical to Canada's EV battery supply chain are presented in the adjacent image.



5. Provincial Initiatives

Ontario has positioned itself as a leader in the EV battery industry through strategic investments, innovative programs, and robust support for R&D. OVIN plays a fundamental role in this landscape, fostering collaboration between industry, academia, and government to accelerate advancements in EV battery technologies.

5.1 Government Initiatives Supporting the EV Battery Supply Chain

Ontario has implemented several initiatives to strengthen the EV battery supply chain, ensuring the province remains a leader in this critical sector. One of the key initiatives is the Driving Prosperity plan, now in its second phase, which aims to transform Ontario's auto sector by supporting the development and production of EVs and their components. This plan includes significant investments in the exploration, mining, and production of critical minerals essential for EV batteries.

The Ontario government has also set up a collaborative initiative with the Three Fires Nations, which include the Caldwell First Nation, the Chippewas of Kettle and Stony Point First Nation, and the Three Fires Group. This initiative is called the Three Fires Nations-Ontario Southwestern Ontario Infrastructure and Economic Opportunities Table, and it aims to accelerate key infrastructure projects, support transformational clean energy project investments, identify and prepare investment-ready lands, and advance discussions regarding shared environmental priorities.

Other initiatives established by the Ontario government to support companies across manufacturing sectors include the Southwestern Ontario Development Fund, the Eastern Ontario Development Fund, the Advanced Manufacturing and Innovation Competitiveness Stream of the Regional Development Program, the Critical Minerals Innovation Fund, and the Invest Ontario Fund.

"The mining and EV sectors are vital to the Canadian economy, creating well-paying jobs in communities nationwide. These industries will address the gap between innovation and commercialization...As the mining industry drives our green recovery and advances us toward net zero, I am pleased to witness the progress we make."

– The Honourable Mary Ng, Minister of Export Promotion, International Trade and Economic Development

5.2 OVIN Initiatives

OVIN plays a crucial role in supporting Ontario's EV battery market through a variety of initiatives and programs. By fostering collaboration between industry, academia, and government, OVIN helps drive innovation and development in EV battery technologies. A number of initiatives delivered by OVIN are outlined below.

Critical Minerals Talent Strategy

In May 2024, OVIN released the Critical Minerals Talent Strategy, a series of strategic reports that expand on Ontario's Critical Minerals Strategy 2022-2027. This initiative is part of OVIN's Workforce and Talent programs and was developed in collaboration with several ministries, including Labour, Immigration, Training and Skills Development; Economic Development, Job Creation and Trade, Northern Development, Indigenous Affairs, and Mines, along with stakeholders from the mining industry.

The strategy addresses the labour opportunities and challenges arising from the growing demand for critical minerals used in EV batteries and the broader electrification value chain. It emphasizes the need to fill thousands of job vacancies to build a robust and skilled workforce in the critical minerals, automotive, and mobility sectors. Key opportunities highlighted in the strategy include engaging youth to raise sector awareness, improving access to training and education, and fostering engagement with women, Indigenous communities, and other underrepresented groups.

OVIN Talent Development Internship / Fellowship Program

OVIN provides two talent development programs through the Talent Development Internship/Fellowship Program. The Internship Program supports college and university students, recent graduates, and Master's graduates, while the Fellowship Program is designed for PhD graduates and post-doctoral fellows. Both programs offer participants the chance to gain industry experience in CAV technologies, EVs, battery technologies, and metal and mining technologies.

OVIN R&D Partnership Fund

OVIN's R&D Partnership Fund supports Ontario-based SMEs through various streams, each targeting a specific focus area. The EV Streams 1 and 2 assist in the development, testing, and validation of EV and battery technologies, with Stream 1 offering co-investment up to $100K and Stream 2 up to $1M.

OVIN Regional Technology Development Sites (RTDSs)

In 2022, OVIN introduced its Northern RTDS, known as CORE5, which spans the northern Ontario region, including North Bay, Sault Ste. Marie, Greater Sudbury, Temiskaming Shores, Timmins, and Thunder Bay. The RTDS aims to unite organizations from the mining and manufacturing sectors, higher education institutions, Regional Innovation Centres, incubators and accelerators, municipal and regional resources, industry, and other regional collaborators. This collaboration supports the development of Ontario's EV supply chain at every stage, from mining and refining raw materials to designing battery cells and EV powertrains, and manufacturing.

OVIN Learn

OVIN has created a central online learning platform called OVIN Learn. Accessible to industry professionals, post-secondary institutions, and the workforce through OVIN's Content Partnerships Program, this platform aims to help talent in Ontario's automotive industry

develop new and existing skills that align with sector needs. The platform emphasizes micro-credential opportunities to upskill the workforce, address future skill requirements, and promote Ontario's automotive ecosystem on a global scale.

The battery-related courses on OVIN Learn include, but are not limited to, the following, with more to be added:

- Electric Vehicle Awareness: Battery Service, Maintenance and Driver Awareness
- Electric Vehicle Awareness: Battery Structure, Safety and Standards
- EV Safety & Awareness
- Introduction to Fuel Cell Electric Vehicles

OVIN Regional Future Workforce Program

"Electrifying the Future" was a project for elementary and high school students, delivered by Laurentian University as part of OVIN's Regional Future Workforce Program, designed to build skills and raise awareness of careers and post-secondary programs for the automotive and mobility sector. It included a two-day student competition called Electrifying the Future MineOpportunity Games and two weeks of summer day camps. The program highlights the importance of collaboration across industries, academia, non-profits, and school boards, securing 47 partnerships, which contributed over $205K in funding and in-kind support for its summer camps and MineOpportunity games. Key partners included: private sector companies like Epiroc, Technica Mining, and Glencore; post-secondary institutions such as the University of Waterloo and Cambrian College; and organizations like MineConnect, the City of Greater Sudbury, and Science North.

OVIN Incubators Program

The OVIN Incubator program is an initiative delivered by OVIN in collaboration with Mercedes-Benz. This program aims to foster innovation in the automotive and mobility sectors by supporting startups and scale-ups in Ontario. The program leverages the expertise of Mercedes-Benz and the resources of OVIN to help startups progress from concept to commercialization. It is the first incubator program of its kind across Canada, providing support to bridge gaps between applied research and the commercialization of IP to enable the rise of new, Ontario-based automotive and mobility companies and connect them with global customers.

"The OVIN Incubators build a robust foundation for nurturing the next generation of innovators by providing a clear pathway from research and development to commercialization and industrialization, in partnership with Ontario's leading postsecondary institutions and major industry players. This platform will further cement the foundation for sustainable economic growth within the sector and beyond, across the entire province."

- Raed Kadri, Head of OVIN

OVIN R&D Partnership Fund: A Success Story in Developing Ontario's Supply Chain

OVIN's R&D EV Stream 2 has enabled the following partnership projects, directly supporting the advancement of Ontario's domestic EV battery supply chain.

Green Graphite Technologies

Li-ion batteries require high purity graphite coated with amorphous carbon. Green Graphite Technologies Inc. is developing process technologies to produce high purity graphite from mined graphite (GraphPure™) as well as from secondary sources (GraphRenew™). Rain Carbon Inc. is a global carbon products manufacturer with an operation in Hamilton, Ontario. It produces the specialty carbon precursor material that is currently used to coat Li-ion battery-grade graphite in China.

Green Graphite Technologies patented purification technology and Rain Carbon's coating will be assessed and compared to existing commercial Li-ion battery-grade graphite. Performance and key engineering data generated by this project will be used to prepare a roadmap for scale up and commercialization. This project is a key step towards establishing an Ontario based supply of high purity, coated graphite for the Li-ion battery manufacturing industry, a key element of the EV supply chain ecosystem.

Battery Grade Materials & Weber Manufacturing Technologies

Rechargeable EV batteries contain significant quantities of nickel. This project will investigate, on a demonstration scale, the application of carbonyl technology to the extraction of nickel from various new nickel concentrates that are expected to become available in coming years as new nickel mining capacity is developed. The project partners include: Battery Grade Materials Inc., a subsidiary of United States-based battery manufacturing company Æsir Technologies Inc.; Weber Manufacturing Technologies, a Midland, Ontario based company with over 20 years of experience in vapometallurgical processing of nickel; and VPM Research, a vapometallurgy consulting and additive manufacturing technology development company founded in 2018 at the Waterloo Accelerator Center and currently operating from Mississauga, Ontario.

A modular nickel foam and nickel powder demonstration production facility will be initially operated at Weber's existing facilities in Midland. The downstream battery manufacturers will be supplied with nickel units from vapometallurgy-based processing of various nickel and iron containing feedstock materials. The final project output will be a modular facility capable of evaluating the vapometallurgy approach to the production of nickel and iron-based battery-grade materials, paving the way for the design of a scaled-up plant for cathode precursors to supply the growing rechargeable battery industry in Ontario and elsewhere.

6. Cross-Industry Influences

The EV battery industry is intricately linked with several other sectors, each playing a crucial role in its development and sustainability. The mining industry is fundamental, providing essential raw materials like lithium, cobalt, and nickel, which are critical for battery production. Innovations and sustainability practices in mining can significantly influence the cost and environmental impact of EV batteries. The energy sector also impacts the EV battery industry through advancements in renewable energy sources and enabling favourable conditions for battery manufacturers via government incentives. Additionally, the automotive industry drives demand for EV batteries and influences their design and performance requirements. Collaboration between these industries can lead to advancements in battery technology, improved supply chain resilience, and enhanced sustainability practices, ultimately shaping the future of the EV battery market.

6.1 Mining

Supply Chain Stability

The availability and stability of raw material supplies directly affect the production and cost of EV batteries. Disruptions in mining operations can lead to shortages and increased prices, impacting the overall EV market.

Sustainability Practices

The environmental and social practices of mining companies influence the sustainability of the entire battery supply chain. Responsible mining practices, including reducing carbon emissions, minimizing environmental damage, and ensuring fair labour conditions, are essential for creating sustainable EV batteries.

Economic Impact

The supply of critical materials can influence market prices, which is directly reflected in the cost of manufacturing EV batteries. Recent decreases in raw material prices have led to reductions in the cost of EV batteries, subsequently making EVs more accessible to a wider audience..

6.2 Energy

Increased Supply of Renewable Energy

As Ontario invests more in clean energy sources, such as nuclear, wind, and solar, the availability of sustainable power for manufacturing processes will increase. This shift not only reduces carbon footprints but also can lower operational costs for battery manufacturers.

Job Creation

The growth of the clean energy sector and EV battery manufacturing can create new job opportunities. Both industries require highly skilled professionals, with the availability of a skilled workforce being a key contributing factor for growth.

Policy and Regulation

Policies favouring sustainability can lead to favourable conditions for battery manufacturers, including tax incentives or subsidies. The government currently offers support for businesses located in the province, by providing electricity to manufacturing companies at reduced costs through the Northern Energy Advantage Program (NEAP) and the Comprehensive Electricity Plan.

Research and Development

The energy sector's investment in R&D can lead to breakthroughs in clean energy technologies, such as EV batteries. Innovations in energy storage, efficiency, and materials can enhance the performance and reduce the cost of EV batteries.

6.3 Automotive

Demand Generation

The push towards EVs by automotive manufacturers and government policies globally drives the demand for EV batteries. As more automakers commit to electrifying their fleets, the need for advanced and efficient batteries increases.

Innovation and Development

Automotive companies invest heavily in R&D to improve battery technology. This includes enhancing energy density, reducing charging times, and increasing the overall lifespan of batteries, which directly benefits the EV battery industry.

Sustainability Initiatives

The federal government has implemented several policies to promote sustainability in the automotive sector, which in turn impacts the EV battery industry. Key initiatives include the iZEV Program, the ZEVIP program, and the mandatory target for 100% of new light-duty car and passenger truck sales to be zero-emission by 2035.

6.4 Aerospace

Technological Innovation

The aerospace sector has stringent requirements for energy density, safety, and reliability in battery technology. Aerospace applications also demand batteries which can perform under extreme conditions. Requirements for electric aircraft may lead to innovations in battery chemistry and thermal management, leading to the development of more robust and efficient batteries which can be adapted for use in EVs.

6.5 Semiconductor

Efficiency and Performance

Semiconductors are crucial for power management systems in EVs, ensuring efficient energy use and extending battery life. Innovations in semiconductor materials like Gallium Nitride (GaN) and Silicon Carbide (SiC) enable EV batteries to operate at higher voltages and temperatures. Semiconductor advancements can also lower the cost of battery production by improving manufacturing processes and reducing material cost.

"Canada is one of the few countries in the world that has everything it needs to be a global leader in EV and battery manufacturing: talent, green energy, and critical minerals."

- The Honourable François-Philippe Champagne Minister of Innovation, Science and Industry of Canada

7. Ontario’s Ecosystem

Ontario boasts several competitive advantages in the realm of EV batteries, starting with a long history of mining know-how, Ontario is well-positioned to support the entire EV battery supply chain, from raw material extraction to processing and manufacturing. The province's strong automotive heritage and significant manufacturing footprint further enhance its competitive edge. Ontario has a skilled and talented workforce, with a deep pool of engineers, technicians, and researchers who are well-versed in automotive and battery technologies. Leading institutions and companies in Ontario are at the forefront of battery research and innovation, driving advancements in battery efficiency, safety, and sustainability.

7.1 Research & Development

CHARGE Lab

Location: University of Windsor

- Research facility with a focus on transformative EV technologies. Helps to foster collaboration across disciplines amongst materials, mechanical, electrical, and software engineers.
- Four major research programs: traction e-machines, traction motor drives and controls, e-motor and drive testing, and battery management systems and chargers.

FLEX-ION Battery Innovation Center

Location: Windsor

- Auto parts manufacturer Ventra Group announced investment of $18.5M in 2022 to create the FLEX-ION Battery Innovation Center, which aims to advance battery chemistries, and cell, module, and pack manufacturing for future EV applications.
- Full scale pilot line offers production-level capabilities to provide proof of concept to full scale production validation.

NRC Battery Performance and Safety Evaluation Research Facility

Location: Ottawa

- Offers safety assessment testing, performance analysis, and environmental analysis of battery packs and cells for both industry and governmental organizations.
- Facility has tested batteries for some of the most renowned automakers and provided them with guidance to facilitate in-house testing.

OBEC

Location: University of Waterloo

- Aims to advance next-generation EV battery development, battery materials production, recycling, and advanced manufacturing.
- Facility will also serve as a training ground for students and post-doctoral fellows and support start-ups and larger businesses in the EV battery supply chain.

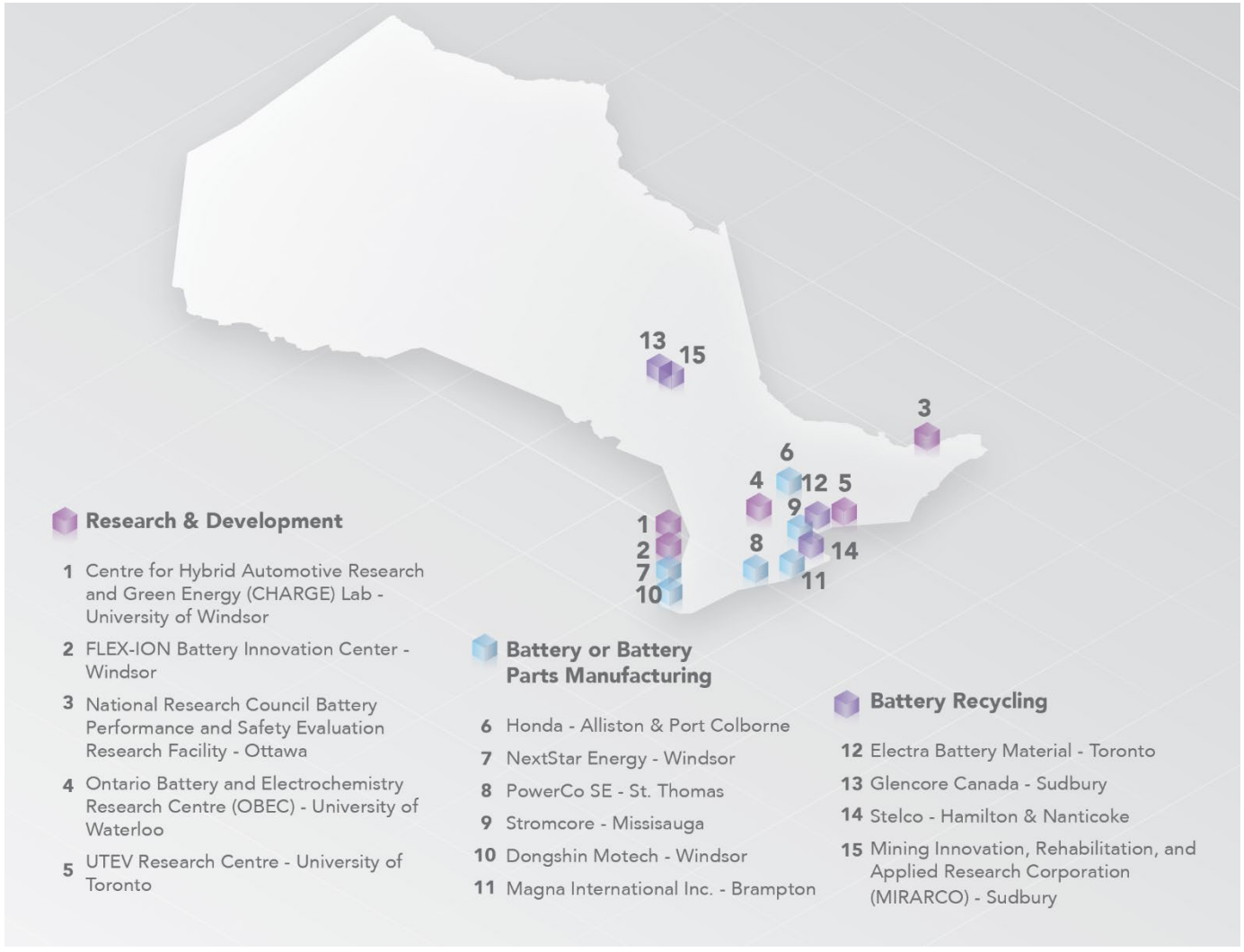
UTEV Research Centre

Location: University of Toronto

- University-industry partnership dedicated to EV technology innovation and research, which serves as a hub for advanced EV research with its state-of-the-art battery and power electronics lab.
- Facility focuses on enhanced energy management, next-generation powertrains, ubiquitous charging, energy storage for EVs, advanced power modules, and expanding the utility of EVs and batteries.
- Scope includes exploring multidisciplinary collaborations among researchers in electrical, computer, mechanical, industrial, and aerospace engineering, as well as developing chargers capable of transferring power from EV batteries to the grid, homes, and other EVs.

Other Research Institutions

- McMaster University conducts research initiatives in advanced manufacturing and battery materials, primarily through the McMaster Automotive Resource Centre.
- Queen's University engages in battery research, including energy storage solutions and materials development.
- Western University focuses on battery technologies and energy storage systems, including research on Li-ion batteries via its Advanced Manufacturing Park.
- York University conducts research related to sustainable energy systems and materials for batteries.
- Ontario Tech University specializes in EV technology and energy storage, offering specialized programs and research opportunities.



7.2 Battery or Battery Parts Manufacturing

Honda

Location: Alliston and Port Colborne

- Announced $15B investment in April 2024 to expand EV manufacturing operations in North America.
- Includes a 36 GWh battery manufacturing plant in Alliston, battery technology (separator) factory in Port Colborne (in partnership with Asahi Kasei), and a battery materials processing plant in collaboration with South Korea's Posco Chemicals (location yet to be disclosed).

PowerCo SE

Location: St. Thomas

- Battery company owned by Volkswagen.
- Announced a $7B investment in 2023 to construct a 90 GWh EV battery manufacturing plant, which will be the largest battery manufacturing plant in Canada and Volkswagen's first outside Europe.

NextStar Energy

Location: Windsor

- Joint venture between automaker Stellantis and battery manufacturer LG Energy Solution.
- Announced a $5B investment in 2022 to construct a 49 GWh EV battery manufacturing plant which will directly supply Stellantis manufacturing plants in Windsor and throughout North America.

Dongshin Motech

Location: Windsor

- South Korean company which specializes in manufacturing aluminum casings for EV batteries.
- Announced a $60M investment in 2022 to build a brand-new 170K square foot facility in Windsor, which will be a direct supplier to NextStar Energy's battery manufacturing plant.

Stromcore

Location: Mississauga

- Designs and manufactures industrial Li-ion battery systems for forklift trucks which are up to 50% more efficient than comparable products on the market.
- In 2023, the federal government announced a $4.8M investment in Stromcore to launch two new products: Turbo Bank, an advanced AI-powered charger with enhanced efficiency, and Electric Cart, a low-emission e-forklift.

Magna International Inc.

Location: Brampton

- Announced a $470M investment in 2023 to expand its automotive parts manufacturing operations across Ontario.
- Investment includes a 490K square foot factory in Brampton which will manufacture battery enclosures for EVs.

7.3 Battery Recycling

Electra Battery Materials

Location: Toronto

- Launched a battery recycling demonstration plant in Temiskaming Shores in 2023.
- Uses a proprietary hydrometallurgical process, boasting a lower carbon footprint and higher metal recovery rate compared to the pyrometallurgical smelting process used by other North American recyclers.
- Received a $5M award from Natural Resources Canada in June 2024 to further develop its proprietary battery metals recycling technology.

Glencore Canada

Location: Sudbury

- Leading recycler of end-of-life electronics.
- Sudbury plant has had battery recycling capabilities since 2004.
- Sudbury Smelter is one of the world's largest processors of complex secondary nickel and cobalt.

Stelco

Location: Hamilton and Nanticoke

- Operates steel manufacturing facilities in both Hamilton and Nanticoke.
- Revealed plans in 2022 to expand the Lake Erie Works in Nanticoke to recycle end-of-life EVs and their batteries.
- Expansion will include a hydrometallurgical refinery capable of recovering up to 18.4K tonnes of valuable materials from EV batteries and up to 40K tonnes of scrap steel from EVs.

MIRARCO

Location: Sudbury

- Not-for-profit research arm of Laurentian University.
- Awarded a $5M grant from Natural Resources Canada in June 2024 towards advancing the recovery of battery metals from mines located in the Greater Sudbury area.

"By harnessing advanced manufacturing processes and emerging technologies, and leveraging the critical mineral wealth in Northern Ontario, our province has what it takes to develop and build the car of the future, and the batteries those cars need."

- The Honourable Victor Fedeli, Ontario Minister of Economic Development, Job Creation and Trade

Electra Battery Materials: A Success Story in Developing Ontario's Supply Chain

Electra Battery Materials has emerged as a unique asset in Ontario, providing a link between upstream raw material extraction and downstream battery manufacturing. The organization's strategic location in Temiskaming Shores connects the mines in the north of the province with the battery manufacturing plants in the South.[14] By focusing on sustainable and ethically sourced battery materials, Electra has significantly contributed to the development of a robust and environmentally friendly EV ecosystem in North America. Electra's battery grade cobalt sulfate refinery is a cornerstone of its operations, establishing itself as North America's first localized and environmentally sustainable refinery for the EV battery supply chain. China has historically dominated in this space, and so Electra presents the opportunity to reduce reliance on China, taking advantage of Ontario's rich critical minerals history, with minerals like nickel and cobalt. Electra is well-positioned to leverage these resources, with aspirations of enabling Canada to become the North American, and moreover Atlantic region powerhouse of battery raw materials.[15] In addition, Electra is actively working to meet upcoming European legislation that mandates minimum recycled content for materials like nickel, cobalt, lithium, and graphite by 2031. To meet these targets, Electra is leveraging its existing hydrometallurgical recycling line and primary cobalt sulfate line. Although initially recycling alone won't suffice to fill the cobalt sulfate line, Electra could gradually replace primary hydroxide with recycled hydroxide produced from black mass.[16]

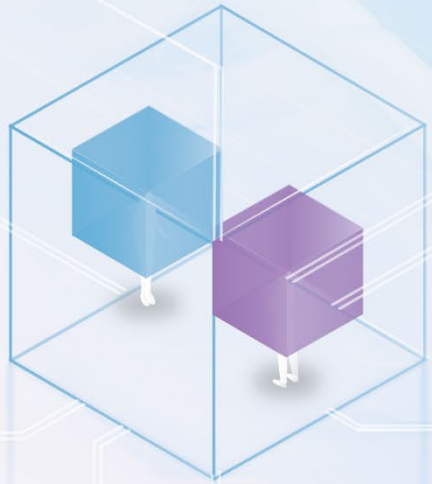
Despite challenges related to the cost of capital in establishing large scale projects in Canada, which can hinder progress, Electra has been successful in securing some of the financing required to launch its flagship refinery.[17] The organization was granted USD $20M in funding by the United States Department of Defense in August 2024, with the objective of supporting the expansion of North America's domestic battery grade materials production capabilities. The organization has also secured $5M in funding from Natural Resources Canada to support the development of its proprietary battery recycling technology.

The EV battery supply chain in Ontario requires a diverse set of skills, not just in terms of engineers and project managers, but also trades, including electricians, pipe fitters, instrument technicians, and millwrights. Electra Battery Materials recognizes the importance of these roles and is actively working to support upskilling in the industry. By partnering with universities and colleges, Electra is helping to develop the next generation of leaders and skilled workers. This collaboration supports building a steady supply of trained professionals who can meet the demands of this rapidly growing sector. Electra's commitment to education and training not only addresses the current skills gap but also secures a sustainable future for the EV battery supply chain in Ontario and beyond.[18] Electra Battery Materials stands out as a pivotal asset in Ontario's EV battery supply chain, bridging the gap between raw material extraction and battery manufacturing. By leveraging Ontario's rich mineral resources and focusing on sustainable practices, Electra is reducing reliance on foreign sources, and positioning Canada as a leader in battery raw materials.

This Success Story was written with contributions from Heather Smiles and Michael Insulan of Electra Battery Materials.

8. Opportunities for Ontario

Ontario stands at a decisive moment in the evolution of its EV battery industry. As global demand for sustainable transportation solutions surges, Ontario has the opportunity to solidify its position as a leader in this transformative sector. By leveraging its strong manufacturing base, skilled workforce, and commitment to innovation, Ontario can drive economic growth, create high-quality jobs, and contribute significantly to global efforts in reducing carbon emissions.



8.1 Establish provincial battery strategy

Establishing a comprehensive battery strategy, akin to the Canadian Battery Innovation Roadmap (published August 2024), is essential for the growth of Ontario's EV battery industry. This strategy would provide a clear framework for advancing battery technology, fostering innovation, and ensuring sustainable practices throughout the battery lifecycle. By setting ambitious goals and outlining specific actions, Ontario can attract investment, support R&D, and build a skilled workforce.

8.2 Continue to foster growth of homegrown supply chain

While Canada has excelled in attracting foreign investment for downstream supply chain applications, ranking third in the OECD in Q1 2023, it is crucial for the federal and provincial government to also prioritize supporting homegrown companies. By establishing local production facilities, Ontario can reduce its reliance on international supply chains, which are often subject to disruptions and geopolitical uncertainties. This move would not only ensure a steady supply of batteries for the burgeoning EV market but also create high-quality jobs and stimulate economic growth within the province. Furthermore, local manufacturing can enhance innovation through closer collaboration between research institutions and industry, leading to advancements in battery technology and production efficiency.

While investments in downstream automotive facilities are essential, the primary challenge lies in securing a steady supply of critical minerals and battery materials upstream and improving the processing of cathode materials midstream. Efforts should be directed towards developing alternative sources and enhancing midstream processing capabilities to support battery production. Although progress is being made upstream and downstream, addressing the midstream challenges is crucial for a robust and efficient supply chain.[19]

8.3 Improve supply chain transparency

Improving supply chain transparency is crucial for the sustainable growth of Ontario's EV battery industry. Implementing initiatives like “battery passports” can play a pivotal role in this effort. These digital passports would track the lifecycle of batteries from raw material extraction to manufacturing, usage, and recycling. By providing detailed information about the origin and processing of materials, battery passports can help ensure ethical sourcing, reduce environmental impact, and enhance consumer trust.

8.4 Continue to promote Ontario as a lead supplier of critical minerals

There is an opportunity for Ontario to position itself as a premier supplier of secure, sustainable critical minerals for the North American battery value chain to leverage further investments in processing and production. Ontario’s access to crucial metal and mineral resources is a significant strength and an attractive proposition for global companies and investors interested in battery-related projects. Establishing reliable sources of these minerals has become increasingly vital for Ontario and its trading partners, especially given recent supply chain disruptions. The proximity to these critical reserves provides a notable advantage as global companies and allied regions strive to localize

supply chains, minimize the distance heavy batteries need to travel, and vertically integrate to reduce production costs. Regionalization of the supply chain enables it to become more resilient to disruptions, ensuring a more stable and reliable supply of batteries.[20]

8.5 Maintain and expand clean electricity grids

Continuing to not only maintain clean electricity grids but also expand them will increase the province's clean electricity capacity and enable Ontario to attract more clean investments, generate jobs, and drive economic growth. Recent studies by Clean Energy Canada indicate that electricity generated from wind and solar is already among the most cost-effective options and is expected to become even cheaper, which could contribute to more cost-effective battery production.

8.6 Streamline permitting process

As Canada enters the next phase of its battery industry development, Ontario can foster growth by addressing existing bottlenecks and enhancing competitiveness. A key first step is to streamline the permitting process. This will facilitate the process for companies looking to scale up and further promote the region as an appealing investment destination. Making approval processes for permits and impact assessments more streamlined and efficient across the battery supply chain – from opening new mines, to battery recycling plants – is essential to unlocking the province's wealth of battery minerals and materials. Locate battery production close to demand centers

Locating battery production facilities close to demand centers is a strategic move for Ontario's EV battery industry, ensuring efficient supply chains and reducing transportation costs and emissions related to the shipment of heavy batteries. By situating production near major automotive hubs, Ontario can better meet the needs of local manufacturers, supporting just-in-time delivery systems, and a more resilient, stable, and reliable supply chain.[21]

8.7 Continue to promote international partnerships and Ontario's global impact

Launching an international outreach initiative to establish partnerships with leading battery research institutions worldwide will greatly enhance Ontario's standing in the global battery industry. In this context, initiatives like Going Global, launched through OVIN, hold considerable potential to support SMEs in expanding internationally. This initiative provides Ontario companies with opportunities to enhance their global presence, showcase innovations, and establish strategic partnerships within the international innovation ecosystem.

International partnerships can also present investment opportunities. Experts note that access to venture capital is a crucial factor in the growth of the EV industry in Ontario. Partnerships are crucial for the Ontario EV battery industry, as increased government investment and collaboration with international players are essential to stay competitive. The global nature of the supply chain underscores the importance of forming global partnerships to drive innovation and maintain competitiveness.[22] Additionally, geopolitical alignments with countries like South Korea, Japan, and some European nations highlight the importance of these collaborations in enhancing Ontario's competitiveness in the global market.[23] Ontario boasts all the essential components: abundant critical minerals, robust R&D capabilities, green energy sources, and close proximity to major markets. Coupled with a

business-friendly regulatory environment, it's clear why global companies are eyeing Ontario as a pivotal player in the EV battery and storage industries.[24]

8.8 Continue to facilitate start-up / industry partnerships

Fostering collaborations between start-ups and established companies is crucial for leveraging expertise and infrastructure to scale operations effectively. This strategy enables start-ups to tap into the advanced resources, facilities, and networks of established firms, which are vital for speeding up development and commercialization. Through these partnerships, start-ups gain mentorship and guidance from industry veterans, boosting their chances of success. Established companies, in turn, benefit from access to cutting-edge technologies and fresh, innovative solutions, enhancing their competitive edge. By encouraging these collaborations, Ontario can build a dynamic ecosystem where both start-ups and established firms flourish, driving growth and innovation in the battery industry. Expand Li-ion battery recycling

As demand for battery materials is projected to continue rising over the next two decades, the security of mineral supply can sometimes be uncertain. This creates a significant opportunity for Ontario to invest in recycling end-of-life batteries, which can serve as a reliable source of critical minerals.

The global volume of battery materials available for recycling is expected to increase seven-fold, from 2020 to 2030, reaching an estimated 1.4M tons. By 2040, this figure is projected to exceed 7M tons. Investing in Li-ion battery recycling not only supports sustainability but also positions Ontario as a leader in the growing circular economy for EV batteries. By continuing to invest in local recycling facilities, Ontario can reduce dependency on imported minerals, create jobs, and enhance its competitive edge in the EV market.

8.9 Continue to develop a skilled workforce

By investing in education and training programs focused on battery technology, manufacturing, and sustainable practices – such as fellowship programs for postgraduate and doctoral research and apprenticeship programs – Ontario can ensure a steady pipeline of qualified professionals ready to meet industry demands. Collaborations between educational institutions, government, and industry can create specialized curricula and apprenticeship opportunities, equipping workers with the latest skills and knowledge. Additionally, initiatives to attract and retain talent, such as competitive salaries and career development programs, will help build a robust workforce. This focus on human capital not only supports the growth of the EV battery sector but also enhances Ontario’s overall economic resilience and innovation capacity.

8.10 Continue to provide access to testing and demonstration facilities

Continuing to provide access to testing and demonstration facilities, such as the OVIN Demonstration Zones and Technology Pilot Zones, is crucial for the growth and success of Ontario's EV battery industry. These facilities offer invaluable resources for companies to test and validate their technologies under real-world conditions, ensuring they meet industry standards and performance benchmarks, and as such there is an opportunity to expand their offering to testing EV battery technologies. By enabling rigorous testing and demonstration, these

facilities can help accelerate the development and commercialization of innovative battery solutions. Moreover, they foster collaboration between industry, academia, and government, driving technological advancements and attracting investment. Maintaining and expanding access to such facilities will ensure Ontario remains a competitive and leading player in the global EV battery market.

8.11 Support establishment of a new battery research center

Establishing a battery research center in Ontario is essential for driving innovation and competitiveness in the province's burgeoning EV battery industry. Given that the automotive sector is heavily concentrated in Southern Ontario, it is an ideal location for a dedicated battery research center, and would provide vital support to this key industry, driving technological advancements and economic growth. A dedicated research facility would foster collaboration between universities, industry leaders, and government agencies, accelerating the development of cutting-edge battery technologies. It would also attract top talent and investment, positioning Ontario as a global leader in sustainable energy solutions. By focusing on advanced R&D, the center would help overcome technical challenges, improve battery performance, and reduce costs, ultimately supporting the transition to a greener economy.

8.12 Continue to support existing research centers

Strengthening the capabilities of Ontario's existing battery research centers, such as OBEC at the University of Waterloo, the CHARGE Lab at the University of Windsor, and the UTEV Research Centre at the University of Toronto, is essential for the province to attain global leadership in battery technology. Increased investment in these centers for training programs and advanced equipment will greatly enhance their research capacity and technological resources. Cutting-edge testing and validation equipment can aid firms and startups by offering access to state-of-the-art facilities, promoting faster innovation and facilitating collaboration with leading researchers. This strategic emphasis on Ontario's research infrastructure will propel technological advancements and establish the province as a frontrunner in the global battery industry.

"Southern Ontario has a rapidly growing EV sector and is home to many leading manufacturers across the EV supply chain that are using their expertise and talent to drive our EV sector forward. The Government of Canada is committed to supporting these companies as they help Canada to make progress towards its goal of reaching net-zero emissions and build a competitive EV sector in the region."

– The Honourable Filomena Tassi, Minister responsible for the Federal Economic Development Agency for Southern Ontario (FedDev Ontario)

9. Expert Interviews

The following experts were consulted during development of this report:

- Daniel Harrison, Automotive Analyst – Ultima Media
- Dr. Tom Vöge, Director Public Policy – GRS Service
- Jonathan Leape, Senior Infrastructure Advisory Consultant – Arup
- Anthony Bruzzone, Associate Principal – Arup
- Nadia Mykytczuk, President & CEO – MIRARCO
- Ali Amadee, Partner & National Head of Battery & Energy Storage Group – Dentons
- Anoosh Loertscher, Associate – Dentons
- Oleksandr Voznyy, Associate Professor – University of Toronto
- Tom Bedford, Executive Director, Strategic Projects Office – Ministry of Economic Development, Job Creation and Trade (MEDJCT)
- Bryan Tyers, Executive Director, Advanced Manufacturing – Invest Ontario
- Stefano Sanguigni, Director, Investor Services – Invest Ontario
- Heather Smiles, Vice President, Investor Relations & Corporate Development – Electra Battery Materials
- Michael Insulan, Vice President, Commercial – Electra Battery Materials

10. Glossary

BEV	Battery Electric Vehicle	**IEA**	International Energy Agency
CAD	Computer Aided Design	**IRA**	Inflation Reduction Act
CAGR	Compound Annual Growth Rate	**IP**	Intellectual Property
CAV	Connected & Autonomous Vehicle	**iZEV**	Incentives for Zero-Emission Vehicles
CHARGE	Centre for Hybrid Automotive Research and Green Energy	**LFP**	Lithium Iron Phosphate
CNG	Compressed Natural Gas	**Li-ion**	Lithium-ion
ERP	Enterprise Resource Planning	**MIT**	Massachusetts Institute of Technology
ESG	Environmental, Social & Governance	**MRP**	Materials Requirement Planning
EV	Electric Vehicle	**NCA**	Nickel Cobalt Aluminum
FCEV	Fuel Cell Electric Vehicles	**NEAP**	Northern Energy Advantage Program
GaN	Gallium Nitride	**NiMH**	Nickel-Metal Hydride
GM	General Motors	**NMC**	Nickel Manganese Cobalt
GWh	Gigawatt Hours	**NRC**	National Research Council
HEV	Hybrid Electric Vehicle	**OBEC**	Ontario Battery and Electrochemistry Research Centre
ICE	Internal Combustion Engine	**OEM**	Original Equipment Manufacturers

OVIN	Ontario Vehicle Innovation Network
PEM	Polymer Electrolyte Membrane
PHEV	Plug-In Hybrid Electric Vehicle
R&D	Research & Development
RESS	Rechargeable Energy Storage Systems
RTDS	Regional Technology Development Sites
SCADA	Supervisory Control and Data Acquisition
SiC	Silicon Carbide
SME	Small and Medium Enterprises
TWh	Terawatt Hours
V2G	Vehicle-to-Grid
VRLA	Valve-Regulated Lead-Acid
ZEVIP	Zero Emission Vehicle Infrastructure Program

11. About OVIN

The Ontario Vehicle Innovation Network (OVIN) is Ontario's flagship initiative for the automotive and mobility sector, with a mission to drive economic development and catalyze a future that builds safer, cleaner, and more efficient transportation.

Led by the Ontario Centre of Innovation (OCI) and supported by the Government of Ontario through the Ministry of Economic Development, Job Creation and Trade (MEDJCT), Ministry of Transportation (MTO), and Ministry of Labour, Immigration, Training and Skills Development (MLITSD), OVIN is driving the future of the sector by supporting the growth of Ontario-made automotive and mobility innovation, developing a highly skilled workforce, and reinforcing Ontario's role as the global automotive and mobility hub of the future.

OVIN supports Ontario-based automotive and mobility companies to accelerate the development and commercialization of transformative technologies and transportation systems through the following programs:

- Research and Development Partnership Fund
- Talent Development
- Regional Technology Development Sites
- Demonstration Zone
- Technology Pilot Zones
- Going Global

OVIN supports the development of a highly skilled, future-ready automotive and mobility workforce through a number of talent strategy and workforce planning initiatives:

- Strategies and frameworks, including the Talent Strategy & Roadmap, Critical Minerals Talent Strategy, and Reskilling Framework
- Pilots and programs, including the Regional Future Workforce and Content Partnerships
- The OVIN Learning Hub, comprised of the Skills and Career Navigator and Upskilling Platform
- DEI Advisory Committee

The OVIN Central Hub drives the province-wide coordination of activities and resources that reinforce Ontario's position as a leading automotive and mobility jurisdiction. The Central Hub is a focal point for all stakeholders across the province, fostering collaboration between industry, small- and medium-sized enterprises, post-secondary institutions, municipalities, government, and new entrants into Ontario's thriving automotive and mobility innovation ecosystem. Through the Central Hub, OVIN drives public education, research, analysis and thought leadership activities, with the goal of raising awareness around the potential of transformative technologies and growth opportunities for Ontario and its partners.

To find out the latest news, visit **www.ovinhub.ca** or follow OVIN on social media @OVINhub

12. OVIN Objectives

Foster the development and commercialization of Ontario-made advanced automotive technologies and smart mobility solutions

Showcase the Province of Ontario as the leader in the development, testing, piloting and adoption of the latest transportation and infrastructure technologies

Drive innovation and collaboration among the growing network of stakeholders at the convergence of automotive and technology

Leverage and retain Ontario's highly skilled talent, and prepare Ontario's workforce for jobs of the future in the automotive and mobility sector

Harness Ontario's regional strengths and capabilities, and support its clusters of automotive and technology

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14. Disclaimers

This report was commissioned by the Ontario Centre of Innovation (OCI) through a Request for Proposals titled “Ontario Vehicle Innovation Network (OVIN) – Annual Comprehensive Sector Report & Quarterly Specialized Reports,” dated August 30, 2024, and has been prepared by Arup Canada Inc. It is one of five reports covering an analysis of Ontario’s automotive technology, electric vehicle and smart mobility landscape while incorporating implications for the sector’s skills and talent landscape.

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