



Government
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FINAL

**From Mines to Mobility:
Seizing Opportunities for Canada in
the Global Battery Value Chain**

WHAT WE HEARD REPORT

Canada



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A NOTE TO PARTICIPANTS ON THE REPORT

In June 2019, the Government of Canada launched a series of stakeholder engagements to understand how Canada can realize emerging opportunities in the global battery value chain. Our goal was to illuminate how increased economic activity could be generated across the value chain in Canada. Having all the minerals and metals required to produce advanced batteries, a strong research and development ecosystem, and a world-class automotive industry, Canada can be a globally competitive extractor and manufacturer of battery-grade materials. Considering the whole battery value chain, we are also aiming to further the competitiveness of domestic energy storage companies and seek greater integration of batteries in Canada's energy transition.

This conversation was first launched at the MaRS Discovery District in Toronto. The journey has truly been one of discovery for all participants, revealing exciting opportunities for Canada and a wealth of talent from coast-to-coast, eager to grow a dynamic battery industry in this great country.

The discourse progressed through a series of four workshops focused on topics identified by participants at the MaRS forum in June:

1. Financing and De-risking Investments in Battery Mineral Mining and Processing;
2. Battery Manufacturing;
3. Energy Storage Adoption; and
4. Battery Material Recycling and the Circular Economy.

Concurrently, individual discussions were held with stakeholders in Canada, and around the globe, to answer questions raised at these workshops in order to better understand the challenges and opportunities before us. What we have learned from these discussions has been invaluable.

This *What We Heard Report* is the product of these important conversations. Its findings will help guide governments and industry as they work together to build the future of Canada's battery industry. As this report reflects the collective insights and recommendations of experts from across the value chain, this draft is your opportunity to tell the Government of Canada if the prevailing views of the industry have been accurately captured.

Thank you for the time you have taken to participate in this important conversation and the valuable insights you have shared with us. We look forward to your continued engagement as we work to realize the opportunities identified in this report.

EXECUTIVE SUMMARY

Battery technologies are integrated into complex and rapidly growing global industries that provide solutions for the electrification of transportation; consumer electronics; industrial automation; and stationary energy storage for utility-scale, micro-grid, and behind-the-meter power applications. Battery adoption stretches across established and emerging sectors, from mining and transportation to renewable energy.

By 2040, the international market for energy storage will attract US\$622 billion in investment¹. While numerous applications exist, the growth rate and scale of electric vehicle (EV) markets globally will dominate the advanced battery market applications for the next 10 years. The International Energy Agency forecasts that electric vehicles could reach 43 million units per year by 2030, up from 2 million in 2018, with production valued at more than US\$567 billion annually. Even the most conservative estimates envision a multi-trillion dollar global market opportunity that Canada cannot afford to ignore.

The lithium-ion battery is at the heart of this opportunity. Leading battery and automotive manufacturers are moving quickly to establish production hubs that will be at the centre of the battery value chain. Jurisdictions that can quickly position their competitive advantages will be best placed to attract an outsized share of these coming investments. Governments around the globe are recognizing the imperative of being part of this emerging industry and are investing billions to develop domestic battery, electric vehicle manufacturing capabilities, and tomorrow's sustainable technologies.

Canada is well positioned to establish itself as a hub for battery technologies² with known deposits, as well as untapped mineral potential, for each of the minerals required for batteries; a leading battery research community; many start-ups in niche markets; a world-class automotive industry that is well-integrated with the American market; abundant renewable and affordable energy; and a commitment to creating an enabling regulatory environment that gives consumers confidence that Canadian products are produced responsibly.

Currently, Canada is a producer of some battery components and systems, but primarily a buyer of cells and modules. The Canadian battery industry has experienced a decrease in exports and an increase in imports. However, Canada has the potential to reverse this trend and accelerate exports by attracting a global battery manufacturer and growing a domestic industry focused on specialty markets, including stationary storage and battery recycling. Establishing manufacturing capacity for energy storage and EVs in Canada would provide certain economies of scale and related skills and infrastructure to develop in the surrounding market ecosystem. In addition to competing for dominance in the EV market, Canada could also be a key player and position itself as a leader in specialty markets including stationary storage; marine and industrial transportation; and battery recycling. These specialty markets would leverage the local EV market capacity in globally competitive ways. Achieving this will require a sustained effort to develop a domestic battery supply chain that leverages Canada's wealth of natural resources, battery research community, and automotive sector.

¹ BloombergNEF, 2019

² The Battery Initiative and the What We Heard Report does not include hydrogen fuel cell technology

Fully realizing the opportunities for Canada in the global battery value chain will require significant new investments in mineral production and processing, technology development the attraction of global battery manufacturers, as well as the attraction of global battery and electric vehicle manufacturers, while augmenting our domestic demand for batteries in varied end-uses.

There is broad agreement that developing a battery industry that creates economic growth and well-paying jobs for Canadians will require action to create both pull (advanced manufacturing/adoption) and push (mineral production and transformation) forces that will underpin the success of Canada's future industry. Given the interdependencies within the value chain, industry and governments cannot afford to focus narrowly on one segment of the market. Canada must embrace a strategic 'mines to mobility' approach if it is to be an integral part of the global battery industry.

Suggested Actions by Participants

Leverage Canada's Minerals and Metals to Foster a Domestic Industry

Canada has all the minerals and metals required to produce advanced batteries. Establishing a green supply of these materials through exploration, mining, and mineral processing will help attract downstream investment in battery component manufacturing.

Attract a Leading Battery Manufacturer to Invest in Canada

The presence of a leading global battery manufacturer would anchor Canada's battery industry, supporting the growth of both upstream materials production and downstream development of electrified vehicle assembly and stationary storage technologies.

Attract Mandates for Production of Electrified Vehicles

Increasing the production of electrified vehicles would bolster the future of Canada's automotive industry while fueling the growth of a domestic battery industry. Competitive advantages in agricultural, mining, aerospace, and marine transportation should be leveraged to establish Canada as a global leader in speciality battery markets.

Establish Canada as a Global Leader in Stationary Energy Storage

The need to decentralize and increase variation in our power grids, will drive the need for energy storage as we transition to a low-carbon economy. Leveraging our advanced battery research ecosystem we can place Canada at the forefront of the stationary energy storage market, servicing domestic and export markets. This leadership begins by addressing the barriers to fully enabling the integration of storage in electricity systems across Canada as an essential technology to enable the cost-effective electrification and decarbonisation of the Canadian economy.

Own Battery Technologies of the Future and Recycling

Canada is at the forefront of development of next generation batteries and is punching above its weight in battery recycling. Competitive advantages in stationary storage, next generation battery development and recycling should be leveraged so we can support the development of made in Canada intellectual property.

INTRODUCTION

Global momentum towards a clean energy future has accelerated the deployment of sustainable energy technologies that minimize greenhouse gases. One of the fastest growing industries supporting this transition is energy storage particularly advanced batteries required for electrified vehicles and stationary energy storage solutions.

Canada has all the minerals required to produce lithium-ion batteries, the technology that will dominate this market over the coming decade. Canada also has an advanced manufacturing industry, world-class automotive sector, and leading battery research community. Industry leaders strongly believe that these advantages can serve as the foundation for growing Canada's battery industry and establishing it as a significant global player in the emerging global value chain.

The window of opportunity for Canada to realize these opportunities is short as the transformation of the global battery ecosystem is advancing quickly. It is important to note that Canada is competing with other jurisdictions to capture anticipated private-sector investment in this sector.

This *What We Heard Report* is based on a series of engagements that were held with industry, governments, and academia from June to October 2019. The conversation was held through a series of four workshops focused on topics identified by participants at the MaRS forum in June:

1. Financing and De-risking Investments in Battery Mineral Mining and Processing;
2. Energy Storage Adoption;
3. Battery Manufacturing; and
4. Battery Material Recycling and the Circular Economy.

Individual discussions with stakeholders across the country, and around the globe, were also held to answer questions raised at these workshops and to better understand the challenges and opportunities for Canada. This report summarizes what we have learned through these engagements and presents the collective recommendations of participants on how to capitalize on Canada's tremendous potential. This report will help guide governments and industry as they work together to build the future of Canada's battery industry.

Thank you to all of those who participated in the engagement process, sharing their time, energy, and insights in support of this important work.

THE STATE OF CANADA'S BATTERY INDUSTRY

An Emergent, Export-Oriented Industry

China is the dominant controlling force for cell and battery manufacturing globally. As a result, several countries are now competing to establish their own domestic industries. Canada's lithium-ion battery industry is comprised of a small number of export-oriented battery mineral producers, battery component manufacturers, specialty battery pack, component suppliers for electrified vehicle manufacturers, and recycling companies. These firms are dynamic and poised for growth, and the presence of anchor battery firms and increased zero-emission vehicle (ZEV) manufacturing could unleash Canada's full potential.

Canadian companies have shown considerable leadership in both the development and adoption of battery technologies. Several Canadian companies have developed specialized electric vehicles (buses, delivery trucks, forklifts, service vehicles and specialized equipment) which require the assembly of battery packs. Moreover, companies in partnership with Natural Resources Canada have installed a series of energy storage systems as a means of reducing diesel consumption in remote communities. Companies in the transportation sector have shown strong early stage ingenuity and are working to scale up operations.

Exports account for 87% of revenue³ with 59% of exports going to the US due to market proximity, supply chain integration and the Canada-United States-Mexico Agreement (CUSMA). In 2018, exports totalled \$251.8 million. Norway, France and Russia are the second, third and fourth top importers of Canadian batteries with Norway recently becoming a major export destination due to sizable contracts given to Corvus Energy Ltd. for production of battery systems for ferries and other commercial maritime vessels.

For Canada, the opportunities in energy storage are abundant. The Canadian market for batteries is currently concentrated in Ontario⁴, where incentives and electricity prices make it attractive for large commercial and industrial users to install energy storage. The majority of these batteries are imported. 95% of Canada's domestic battery storage demand is supplied by foreign firms, with this number projected to rise, barring further action. In 2018, Canada saw \$1.9 billion in battery imports, primarily sourced from the United States, China, South Korea and Japan. Substituting imports with Canadian supplies represents a significant growth opportunity.

³ IBIS World Industry Report on Battery Manufacturing in Canada

⁴ Ontario (47.3%), British Columbia (23.6%) and Quebec (20.0%) – Global Affairs Canada Office of Chief Economist

Internationally Recognized Research Ecosystem

Canada's battery research ecosystem is robust and internationally recognized. One of the world's first lithium-ion battery manufacturers, E-One Moli Energy, was founded in British Columbia in 1998. This research ecosystem now includes:

- **Academia** – Many universities in Canada have a strong presence in battery research and development. Notable researchers in Canadian universities including Linda Nazar (University of Waterloo), Jeff Dahn (Dalhousie University), Andy Sun (Western University), George P. Demopoulos (McGill University), Mickael Dollé (Université de Montréal), Daniel Bélanger and Steen B. Schougaard (UQAM), Lionel Roué (INRS), and Venkataraman Thangadurai (University of Calgary).
- **Innovative Vehicle Institute (IVI)** – Affiliated with St-Jérôme CEGEP in Quebec, IVI is advancing research in battery pack integration in Canada.
- **University of Toronto Electric Vehicle (UTEV) Research Centre** – a university-industry partnership focused on the development of power electronic converters for EV drivetrains, charging infrastructure, energy storage for EVs and autonomous operation of EVs.
- **National Research Council Canada (NRC)** – The NRC owns very significant infrastructure and has several research teams across Canada working on batteries primarily within the Energy, Mining, Environment (EME), and Automotive and Surface Transportation (AST) research centers. This work is largely organized by industrial end use applications, with programs on Energy Storage for Grid Security and Modernization, and Vehicle Propulsion Technologies. NRC also provides grants and contributions to many small and medium-sized enterprises (less than 500 employees) in the battery supply chain through its regional Industrial Research Assistance Program (IRAP). NRC also runs an industrial research and development group focused on Lithium-ion technology (LiBTec).
- **CanmetENERGY & CanmetMATERIALS & CanmetMINING (Natural Resources Canada)** partners with industry on renewable technology development and conducts research on grid integration of renewables and decentralized energy resources. CanmetMATERIALS works with a variety of materials applications, including the use of artificial intelligence in lithium optimization.
- **Transport Canada's Innovation Centre** is actively engaged in state-of-the-art battery and electric vehicle research, partnering with Environment and Climate Change Canada, Natural Resources Canada, and the National Research Council Canada.
- **Sustainable Development Technology Canada** supports a number of Canada's leading battery companies through development and demonstration financing.
- **Toronto Hydro** was the first company in the world to install a lithium based energy storage system on an electrical distribution network. This system was completed in partnership with **eCamion**, a Canadian manufacturer of battery-based systems.
- **Hydro Quebec's Institut de recherche d'Hydro-Québec (IREQ)** is the largest research centre run by an electric utility in North America, with HydroQuebec investing on average \$100 million a year in innovation projects. In addition, the **Centre of Excellence in Transportation Electrification and Energy Storage (CETEES)** is developing materials and systems in lithium-ion and solid-state lithium batteries.
- **Alberta Innovates** funds a number of start-up companies within Alberta who are investigating new battery chemistries, or the production of battery materials.
- **Quebec-based InnovÉÉ** brings together battery researchers to accelerate battery innovation in the field of electric vehicles and storage technologies, including batteries.

Numerous private sector players also participate in the battery research and development ecosystem, including junior mining companies looking to exploit Canadian resources in graphite, lithium, vanadium; battery material recyclers; including vehicle electrification and energy storage solution developers and integrators across the country.

Similarly, Canada has a significant footprint in R&D and early commercialization of battery recycling processes. Lithion Recycling, Li-cycle, and Retrieval Technologies represent leading Canadian operations that, with public-private investment, could recycle a large portion of lithium-ion battery materials in North America.

Provinces are Taking Action

From Nova Scotia's battery research cluster to Alberta's efforts to explore mining lithium from existing tailings, provinces are moving quickly to establish their role in Canada's battery industry. In September 2019, Propulsion Quebec, an industry cluster created to position Quebec as a leader in electric and smart transportation sector, released a report highlighting significant opportunities for the province along the lithium-ion value chain, echoing the preliminary findings in this report that there is significant potential to foster a domestic battery industry. The report noted that:

"Quebec can build on its strengths to establish a foothold in [the battery] market. Quebec already has the raw materials required for battery production, readily available technological and industrial expertise, access to clean and abundant energy, relatively low operating costs for North America, and proximity to automobile manufacturers".

To fully realize these advantages, the report identifies four promising options for developing a battery industry in Quebec:

1. Implementing stronger vertical integration of the sector by strengthening the capacities of resource and material producers;
2. Working to attract strategic partners and establish partnerships with them to develop a lithium-ion battery-cell or component manufacturing plant;
3. Developing a lithium-ion battery recycling industry based on reliable hydrometallurgical processes (as yet undeveloped); and
4. Adapting current recycling facilities so they can handle end-of-life lithium-ion batteries (e.g. adapt recycling facilities that treat industrial waste using pyrometallurgy).

Given complementary strengths across Canada, including in mineral development, advanced manufacturing, mineral recycling, and advanced battery research, jurisdictions need to coordinate efforts to realize opportunities throughout the global value chain for advanced batteries.

OPPORTUNITIES FOR CANADA & KEY ISSUES

The Global Context

The battery value chain is dynamic. Battery technologies are integrated into complex and rapidly growing global industries that provide solutions for electrified vehicles; transportation electrification; industrial automation; and stationary energy storage for utility-scale, micro-grid, and behind-the-meter power applications. Battery technologies are part of both established and emerging sectors, from mining and transportation to chemical manufacturing and renewable energy. As the industry converges with transformative sectors like artificial intelligence, digitization; robotics; and electrification – batteries and the energy they store will reshape the energy economy. Simon Moores, Managing Director of Benchmark Mineral intelligence, testifying on the outlook for the global battery supply chain to a US Senate Committee, and stated how “... those who control these critical raw materials and those who possess the manufacturing and processing know how, will hold the balance of industrial power in the 21st century auto and energy storage industries.”⁵ Canada and the U.S. have agreed on a joint action plan for the security of critical minerals.

By 2040, the international market for energy storage will attract US\$622 billion in investment.⁶ The International Energy Agency forecasts that electric vehicles could reach 43 million units per year by 2030, up from 2 million in 2018, with production valued at more than US\$567 billion annually. Global lithium-ion battery demand will surpass 2,000 GWh by 2030, driven mainly by the growth of electrified vehicles and stationary storage.⁷ Notably, these forecasts are highly contingent, as government policies, the availability to raw materials, and technological developments could constrain or expand these projections. However, even the most conservative estimates envision a multi-trillion dollar global market opportunity that Canada cannot afford to ignore.

Governments of the world’s leading economies are supporting the growth of their domestic industry by investing billions to attract investments in mining, battery manufacturing, and electrified vehicle production. For example, Australia launched an initiative, which outlines its potential to develop a lithium-based supply chain feeding into a potential lithium-ion battery production. Another example is a fund of one billion euros by the German government to support production of battery cells. These governments recognize that failing to secure a place in the lithium-ion battery value chain will put them on the sidelines of future energy markets.

A number of countries have developed strategies and incentives to encourage investment. Chile hopes to establish processing and battery manufacturing capacity, and is experimenting with new policy levers. Australia is similarly pursuing domestic battery materials processing facilities and has created its “Lithium Valley,” which is an industry cluster, co-located with mining projects, that focuses on the secondary and tertiary processing of lithium and other battery metals.

⁵ US Senate Committee on Energy and Natural Resources Committee, outlook for energy and minerals markets in the 116th Congress. Tuesday, February 5 2019.

⁶ BloombergNEF, 2019

⁷ Ibid

The European Union has announced a €5 billion plan, in collaboration with industry, to spur the growth of continental battery manufacturing and electrified vehicle production. The United States is also in the process of developing a strategy to support its domestic battery industry. The Department of Energy recently announced a US\$120 million investment in a Joint Centre for Energy Storage Research.

Battery Metal Exploration, Mining and Processing

Advanced batteries are comprised of a host of components made with mineral-based precursor materials. Three of these key metals (lithium, nickel, cobalt) contribute ~50-60% of cathode manufacturing cost. Nickel and cobalt are increasingly scarce with supply constraints for nickel projected to occur within the next five years. Countries that are able to provide secure, stable sources of supply will benefit from historic anticipated increases in demand over the next decade⁸:

- Lithium +575%
- Graphite +530%
- Cobalt +256%
- Nickel +1,237%

This rapidly growing demand is already increasing investor interest in Canada's minerals and battery metals processing market. Canada is well positioned to help meet rapidly growing global demand for battery metals with dozens of advanced stage projects⁹ across the country¹⁰.

- Cobalt 17
- Lithium 9
- Graphite 7
- Nickel 23

Refined battery minerals command a significant price premium over the unrefined commodity. For example, lithium is relatively abundant in nature but the process to produce battery-grade material is complex. In June 2019, the spot price for lithium spodumene ore was US\$600 per tonne compared to almost US\$16,000 for refined battery-grade lithium hydroxide.

As battery production increases, demand for mineral-based precursor materials will continue to rise. As one of the world's foremost mining countries, Canada is well placed to build on its existing mineral processing expertise to produce battery-grade materials for cathode and anode manufacturing.

Precursor production is also the re-entry point for recycled battery minerals. Canada can avail itself of this opportunity to become a leader in reusing battery materials and developing a circular economy for the lithium-ion battery industry.

⁸ Benchmark Minerals, 2019

⁹ *Advanced Stage Projects* are defined as projects that have advanced to the Preliminary Economic Assessment stage of development

¹⁰ Natural Resources Canada, 2019. An Advanced Project is defined as having completed at least a Preliminary Economic Assessment

Key Issues

Insufficient investment in upstream production limits the number of new projects that are funded and advanced. Price fluctuations, low margins on certain battery minerals and metals projects, risks associated with processing facilities, and increased competitive production capacity in Asia and South America growth in passive investment, and the rise of alternative high-growth potential investments have combined to curb interest in battery metal projects. In 2018, these trends continued with overall mineral industry equity financing dropping by 35% over the previous year, establishing a decade low for both total value raised and number of transactions completed.

A lack of capital for battery metal processing demonstration projects is preventing upstream companies from serving as the foundation of growth for battery component, cell, and pack manufacturing. Investors are leery of investing in a low-margin mine and high-risk mineral processing facility. An important potential source of investment in battery metal mining and processing is downstream battery manufacturers as well as automotive manufacturers. Relationships between automotive companies, battery manufacturers, chemical companies, and miners need to be strengthened to unlock these downstream sources of capital.

Infrastructure needs in rural, remote, and northern communities limit access to some resource-rich areas. Further investment in transportation and energy infrastructure will be required to unlock the potential of remote battery mineral deposits.

Regulations affect lead times and costs for firms that engage in exploration and extraction activities. Regulatory systems that are strong, agile, transparent, and predictable are a competitive advantage, as they protect the environment, facilitate sound project planning, and provide investors with a clear path to timely project approvals. Clear guidance on permitting processes and regulatory requirements helps battery metal mining projects minimize delays. This is particularly pronounced when it comes to recycling. Governments also need to ensure they continue their efforts to involve Indigenous Peoples in decision-making about mineral resources, particularly when it comes to fulfilling their duty to consult and accommodate.

Battery Manufacturing

The manufacturing of battery components, cells, and packs represents a significant portion of the value-added portions of the battery value chain. While there are multiple chemistries for various applications currently, lithium-ion will be the dominant technology in the medium-term. Global demand for the components that make up lithium-ion batteries (e.g. collector, separator, electrodes and electrolytes) will increase from 1.3 million metric tons in 2019 to over 10.1 million metric tons by 2030.

Lithium-ion batteries are used in both electrified vehicles and stationary storage applications. Battery manufacturers will often supply both markets, and batteries for both markets are commonly manufactured within the same facilities. Battery vendors are rapidly expanding production capacity, locating new manufacturing plants closer to centres of demand and seeking to solidify supply relationships across both industries.

China, Japan, the US and South Korea are the leading producers of battery components and cells. Canada has trade agreements in place with Japan (CPTPP), the US (CUSMA) and South Korea (CKFTA). Asian manufacturers dominate the global battery industry in terms of scale and core competencies around technology and manufacturing. Many of these firms are now setting up production capacity closer to demand centers in Europe and the U.S (e.g. SK Innovation in Georgia, Tesla Gigafactory near Berlin). To date, battery materials and cell manufacturing has been heavily concentrated in Asia, specifically China, which provided 70% of global supply in 2019. BNEF lists China, Japan, Poland and South Korea as the top cathode manufacturing locations.

China is expected to remain the leading global supplier of batteries over the next decade, servicing over 50% of the world's battery demand, including their large domestic market. Despite this advantage, the industry anticipates that higher quality batteries needed by the automotive industry in North America and Europe will likely be produced elsewhere. This presents an opportunity for Canada to enter the battery manufacturing stage of the value chain.

Cathodes are a strategic battery component accounting for roughly 50% of a battery's value. Canada is one of only two countries¹¹ with exploitable deposits of all the metals and minerals required to produce cathodes. By 2021, global cathode production capacity is expected to exceed one million metric tons.¹² This will be sufficient for demand in 2021, but capacity will need to increase another five times by 2030 to keep up. Low-cost, zero-emission hydroelectricity in a number of Canadian provinces is a key comparative advantage in energy intensive cathode production.

Demand for batteries is projected to exceed supply both globally and in North America. According to industry data, forecasted market demand in North America could exceed planned supply by up to 3 times. This results in a gap that will need to be met by new players and by existing players increasing their investment commitments to the region.

To prepare for this future, automotive manufacturers and grid scale storage providers are increasingly active in securing upstream supply. Industry players are seeking vertical integration to have more control over the supply chain, maximize cost synergies, ensure higher quality control, reduce logistic costs, and limit dependency on critical materials.

Since the transportation sector at large and energy storage industries are the primary drivers of growth in the battery industry, Canada could stand to benefit from closer collaboration between upstream and downstream players along the battery value chain.

Although the most significant growth area in the near-term will be lithium-ion batteries for passenger and transit electrified vehicles Canada is also poised to capture specialty markets such as medium and heavy duty trucking, rail, marine, aerospace, delivery vehicles, mining, and agriculture as well as the exponential rise of wearable electronics

¹¹ Second country is Australia, Canada is however the only country with an automotive footprint.

¹² BloombergNEF, 2019

Key Issues

Mineral price volatility is preventing battery manufacturers from securing a consistent source for battery raw materials. Price volatility of battery mineral resources and the inability to accurately forecast prices can significantly undermine any advances made by the economies of scale for production. A key challenge facing the industry will be to ensure continuous adoption of electrified vehicles given the uncertainty associated with cost.

A fragmented value chain where end-use manufacturers are not fully integrated with suppliers of batteries and battery precursor materials is hindering investment in upstream project, leading to anticipated shortage of key battery metals.

Conglomerates in Asia and Europe (LG Chem, Panasonic, CATL, BASF, etc.) currently dominate the manufacturing of battery components. These companies control intellectual property in this vital segment of the value chain. Attracting one or more of these conglomerates to build production facilities in Canada may be one of the most viable pathways to integrating Canada's lithium-ion industry into the global value chain.

Limited manufacturing of electrified vehicles in Canada and North America. The absence of demand for batteries from OEMs in Canada is a primary barrier to domestic battery manufacturing. However, this is a chicken and egg scenario whereby automotive manufacturers are unable to attract electrification mandates to the Great Lakes region without the existing presence of the battery supply chain. OEMs are eager to compete for EV mandates and are very supportive of Canada's efforts to establish the supply chain.

Lack of access to scale-up capital for specialty battery manufacturers in Canada is slowing the growth of the industry. Manufacturing capability is capital intensive, both for initial fixed costs but also sustaining capital.

Lack of available capital for grid upgrades that electricity system operators/utilities need to undertake to update systems, tools and equipment to enable storage and provide grid-level electricity products and services. Electricity system operators/integrated utilities are under significant pressure to contract electricity costs at the same time as they are being forced to make trade-offs about how to use limited capital to address increased cybersecurity threats, increased extreme weather events and to integrate energy storage. Utility tools, systems and equipment were generally developed at a time when storage was not an option. These upgrades are essential to not only unlocking the value of consumer-owned storage to address grid needs but also to maintaining grid reliability in the face of increased storage and end-user level.

No green standard for batteries. The reduction of GHG emissions and pollution is a key driving force behind the electrification of the global economy. Without greening the process of producing the technologies that will underpin this energy transition, the benefits will not be fully captured. The manufacturing of a battery can account for almost 50% of emissions throughout the life of an EV. End-users are increasingly demanding sustainable batteries and cleaner processes. Canada has one of the lowest carbon footprints for producing a 100 kWh NMC battery pack, which is 5x lower than China and 3x lower than the U.S. Canada has an opportunity to bring together like-minded battery manufacturing countries to establish a standard that will improve the environmental impact of battery materials

production and cell manufacturing while growing the market for made in Canada technologies. In addition, while electric vehicle manufacturers are increasingly touting the sustainability benefits of their cars, questions linger on the holistic environmental impacts of electric vehicle and battery manufacturing. Canada has an opportunity to promote a green standard that goes beyond GHG emission reductions to look more holistically at the environmental impacts of battery manufacturing (water, air, soil, energy) in order to position Canadian-made batteries as the clean, green choice.

Stationary Storage

There is a fundamental transition developing in the power system and transportation sector. Falling wind, solar and battery costs mean wind and solar are set to make up almost 40% of world electricity in 2040, up from 7% today.¹³

Nine countries lead the stationary storage market. Two thirds of the market (on a MW basis) is installed in China, the U.S., India, Japan, Germany, France, Australia, South Korea and the U.K. Canada currently has trade agreements with 7 of these 9 countries.

Canada has a natural advantage given that our generation mix is already over 80% non-emitting. However, only 20% of Canadian energy end-use is electrified and many jurisdictions have an uncertain path towards further decarbonisation. Fortunately, energy storage can enable increased adoption of renewable power and the electrification of the transportation sector, which represents over 25% of Canada's total emissions.

Batteries present a particularly interesting opportunity in the energy storage space due to their versatility, modularity and remarkable historic and projected cost declines. Lithium-ion technology appears to be poised to dominate the market for the next decade, however a number of other energy storage technologies show considerable promise as well.

For Canada, these opportunities are abundant, and include enabling e-mobility integration (e.g. co-sited with chargers), rural and remote applications, alternatives to diesel generation for resiliency and back-up power applications (e.g. hospitals), industrial and commercial applications (e.g. Ontario Industrial Conservation Initiative), and grid scale applications (e.g. alternative to natural gas peaker plants). Behind-the-meter storage, micro-grids and rural and remote applications are also areas in which Canada could become a leader, as Canada's domestic firms are technologically capable of supplying hardware to enable these applications at home and abroad.

Key Issues

Perceptions of the relative affordability of energy storage technologies has constrained adoption even as the costs of storage technologies that enable wind and solar energy have been rapidly decreasing.

Incomplete and inconsistent definitions and standards for participation on the electricity grid often linger as barriers for energy storage stakeholders and policymakers. Consequently, energy storage applications and potential value streams remain poorly understood and undervalued in many markets.

¹³ BloombergNEF, 2019

Specific concerns with existing rules among power industry participants who find that existing rules unfairly treat energy storage (e.g. regulatory barriers to “revenue stacking”).

Current domestic demand for energy storage (batteries) in Canada and North America has limited the investments made in upstream segments of the battery supply chain.

Currently no explicit policy measures at the federal, provincial, or territorial level to support energy storage adoption in Canada.

Limited access to capital for scale-up is constraining the growth of domestic energy storage firms. With the exception of a small number of firms, Canada’s energy storage industry faces difficulty in competing on cost with larger international firms.

Electric Vehicles and Electrification of Transportation

The electrification of transportation holds tremendous potential to create jobs and intellectual property in Canada to say nothing of the tremendous opportunity to drastically reduce GHG and CAC emissions in Canada¹⁴. Canada has an opportunity to transform and potentially grow its automotive industry to also include the manufacturing of electrified vehicles including hybrid, plug-in hybrid, fuel cell electric, and battery electric vehicles¹⁵.

The automotive industry is one of the largest manufacturing sectors in Canada, responsible for 10% of total manufacturing gross domestic product and is one of Canada’s largest exporters, making up 14% of total merchandise exports. Driven by the operations of five global automotive manufacturers and close to 700 diverse automotive suppliers, the industry is a key source of value-added manufacturing jobs, employing over 137,000 Canadians directly and another 419,000 indirectly.

Since the signing of the Auto Pact in 1965, Canada has benefited enormously from its participation in an integrated North American market. Automotive manufacturers have invested in Canada, in large part, based on Canada’s stable and consistent commitment thus contributing \$19B to this integrated market. As such, Canada is part of the largest North American automotive cluster running from Ontario through the Great Lakes Region. According to Clean Energy Canada, the clean transport industry will add over 262,000 new jobs (e.g. manufacturing electric cars, buses and trucks) by 2030.

Automakers are increasing their commitments to electrification with over \$141 billion worth of commitments globally in new assembly plants, R&D and roll-out of ZEVs. The manufacturing supply chain is shifting to accommodate large volume production goals. Almost all of the major automotive manufacturers have made announcements related to alternative hybrid and/or electric powertrain models they plan to bring into the market. In addition, new entrants also represent a substantial challenge to the status quo. For example, Tesla is currently dominating the electric vehicle market share, and Chinese electric vehicle makers have signaled their plans for expansion beyond their own – largest - ZEV market.

¹⁴ Transportation accounts for over 25% of Canada’s total GHG emissions.

¹⁵ One of the OEMs in Canada currently manufactures a Plug-in Hybrid vehicle.

According to industry reports, battery demand over the next decade will likely exceed current planned production capacity for North America¹⁶. As the automotive industry continues to undergo a transformational change—driven by new trends that are shaping and defining the vehicle of the future—Canada needs to ensure that it is well prepared to succeed in the global marketplace and retain its automotive manufacturing footprint. Proactive initiatives are important to ensure that Canada is attracting investments in next generation vehicles with various levels of electrification, connected, V2X-enabled) and the respective supply chain necessary to support them.

Supply chains will locate in proximity to electrified vehicle assemblers. While Canada has free trade agreements with nine of the top ten battery electric vehicle producing countries, the North American market will continue to be Canada's primary market due to the integrated nature of the market. The importance of this cannot be overstated as the auto sector has shown a strong preference¹⁷ for component suppliers to be close to manufacturing hubs to ensure supply security and benefits from the cost savings realized by vertical integration. In addition, regionalization will help OEMs meet the regional local content requirements of various trade agreements such as CUSMA and CETA.

Canada is a pioneer in the electrification of niche market vehicles, manufacturing and assembling electric buses, heavy-duty, and all-terrain and recreational vehicles. There are significant opportunities for Canadian companies to seize additional market share in the electrification of other transportation industries, including in aerospace, marine, mining, and agriculture.

In addition to the supply of materials into the battery market, mining companies are increasingly looking towards the electrification of their operations, as energy consumption is one of their largest costs. They are looking to capitalize on the electrification of their vehicles and grid-side demand to reduce costs. Lowering the costs to their operations while reducing volatilities in the markets for the products they produce are key to their success.

Batteries can also be leveraged for purposes other than just powering the vehicle. There are tangible potential benefits to use vehicle batteries to provide power to other uses, such as extending vehicle to grid integration and demand side management for smart-grid and smart-charging technologies.

Key Issues

The competitiveness of the Canadian automotive industry in attracting ZEV production mandates begins with the same competitive variables that shape investment attraction overall. As such, a focus on regulatory alignment, open borders, high quality labour, and financial incentives will remain critical in positioning Canada to compete. Policies that promote electrification and advanced vehicle technologies must build on these building blocks of Canadian competitiveness.

The regional trade dynamics within North America and the rules of origin that shape the movement of goods can influence where ZEV production mandates are announced. Many automakers continue to import significant parts such as batteries and electrified powertrains. If these vehicles fail to meet the regional content requirements in North America, then they cannot be imported or exported across North American borders duty free.

¹⁶ According to industry data, forecasted market demand in North America could exceed planned supply by up to 3 times.

¹⁷ As well as importance of compliance with increased North American content, proposed under CUSMA.

North American electric vehicle sales are expected to continue to lag behind both Europe and China in the coming years. While it is true that OEMs in Canada serve the wider North American market, local market demand still plays a significant role in influencing where mandates are assigned (*“build where you sell”*). However, measures to increase business and consumer demand¹⁸ will continue to grow the market and stimulate further investment in North American production.

The value of a major domestic lithium-ion battery manufacturer

ZEV manufacturers aiming to achieve successful production of electrified vehicles need to establish strong and advantageous partnerships with battery cell manufacturers. These partnerships are critical for ensuring high vehicle performance and for predicting and controlling costs. According to OEMs in Canada, the presence of battery and battery component manufacturers in Canada would leverage investor interest in manufacturing electrified vehicles.

Life-Cycle and Recycling

Opportunities for battery recycling are significant, given the predicted amount of electrified vehicle batteries that will be available for recycling by 2030 and the limited planned capacity for recycling facilities.

Demand for electrified vehicles and stationary storage will create 2 million metric tons of lithium-ion battery scrap available for recycling per year by 2030. In Europe and North America, there are only eight companies currently active in lithium-ion battery recycling. Glencore (Canada) and Umicore (Europe) have the largest capacity, at 7,000 metric tons per year each. The most valuable component in a used battery pack is the cathode active material, which can contain cobalt, nickel and lithium.

As countries manage end-of-life issues pertaining to electric vehicles, regulators will likely require the industry to develop life-cycle management programs such as second-life applications, recycling and safe disposal. This presents both a logistical challenge for manufacturers and an opportunity for battery component manufacturers and others to reduce their reliance on imported materials. Battery vendors are moving upstream to secure access to electrode materials and key metals. An emerging strategy for leading players is to build closed-loop value chains by covering recycling.

Chinese companies are poised to dominate the global battery recycling market, with an estimated 1Mmt per year of recycling capacity already planned by 2030. However, due to the cost and regulations associated with the shipment of batteries, it is unlikely that North American batteries will be recycled overseas.

Canada is already the North American leader in battery recycling with advanced research and development and early commercialization of recycling processes. Although capacity is still limited, Canadian-based companies like Lithion Recycling, Li-cycle, and Retrieval Technologies are among the global leaders in battery material recycling.

¹⁸ Measures include federal purchase incentives for ZEV, support for ZEV charging and refuelling infrastructure, ZEV awareness and voluntary supply agreements with automakers.

Battery manufacturers, automotive manufacturers and recyclers are already organizing through a North American industry association. It will be important for Canada to play a leadership role in shaping the direction of the industry if Canadian firms are to continue to thrive as the market matures.

Key Issues

The opacity of existing battery industry supply chains and the movement of used batteries. More needs to be done to understand how current battery producers are managing end-of-life challenges.

Technical challenges facing battery recycling are numerous. A multitude of chemistries and battery pack designs presents significant challenges to automating recycling processes.

Uncertainty is limiting investment in greening the value chain. Monetizing the value of 'green' recycling technologies has attracted significant interest. However, it is not yet clear the premium that consumers and companies alike are willing to pay for green battery technologies.

The absence of industry standards regarding labeling component parts, post-recycling material quality, and recycling processes all pose challenges to re-introducing recycled materials into supply chains.

The imposition of recycling requirements before scientific data is available to inform their development could impact the decision of automakers to locate and sell electrified vehicles in Canada.

Rules governing the movement of recycled materials has significant implications for market development, particularly as it relates to the harmonization of regulations between the United States and Canada and amongst Canadian provinces and territories. Lithium battery shipment and importing in Canada is subject to regulations and standards outlined by Transport Canada's Transportation of Dangerous Goods (TC-TDG) Program under the *Transportation of Dangerous Goods Act, 1992* (TDG Act). The predominant risk related to the transportation of lithium-ion batteries is the potential for fire. Short circuiting batteries can result in a chain reaction, known as thermal runaway, which can produce quantities of toxic gases and fires that are difficult to suppress by conventional means. Lithium batteries, and lithium batteries contained in equipment, are strictly regulated in transport by all modes in Canada under the *Transportation of Dangerous Goods Regulations* (TDGR) and internationally under the United Nation Model Regulations for the transportation of dangerous goods (UN Model Regulations), the International Maritime Dangerous Goods Code (IMDG Code) and the International Civil Aviation Organization (ICAO). It is required that lithium batteries be appropriately classified, marked, packaged and accompanied with appropriate documentation.

SUGGESTED ACTIONS BY PARTICIPANTS

Stakeholders widely believe that Canada has significant potential to be a recognized value-added producer in the global battery industry, supplying innovative made in Canada solutions built with reliable, sustainable, and responsible minerals and metals.

To grow Canada's battery industry and realize opportunities in the global battery value chain, five key recommendations have been made by industry. Although there are varying views on the actions required to realize these recommendations, there is broad agreement on a number of potential ideas that could be considered by governments and industry to position Canada's battery industry for future success. These ideas follow each recommendation.

Leverage Canada's Minerals and Metals to Foster a Domestic Industry

Canada has all the minerals and metals required to produce advanced batteries. Establishing a robust supply of these materials through responsible exploration, mining, and mineral/chemical processing will help attract investment further downstream in battery component manufacturing.

Potential Actions

Mineral exploration and mining create significant opportunities for employment and wealth generation across the country, in both urban and remote areas. Canada is well-positioned to increase its role as a stable supplier of clean and ethical raw materials and precursors (e.g. cathode materials) for the production of batteries.

For this to occur, however, federal, provincial and territorial governments must:

- Continue efforts to create an enabling environment for responsible mineral exploration and mining, including the funding of infrastructure, improving the efficiency of regulatory processes, and continue efforts to involve Indigenous Peoples in decision-making about mineral resources
- Explore how innovations in public geoscience can help companies more successfully discover new battery metal deposits (e.g. lithium, manganese, aluminum or graphite). For example, geological surveys could increase their research into the potential of each mineral deposit type to host the battery metals of interest in economically relevant quantities, as well as understanding how to locate non-obvious deposits (e.g. far below surface)
- Expand research into geo-environmental conditions associated with the development of relevant mineral deposit types
- Improve geo-environmental research on mine wastes and drainage associated with mineral deposits that host critical and battery metals, to support cleaner, greener mining
- Form partnerships to access capital from the United States and the European Union through political collaboration that could include joint initiatives, trade missions, and supply chain convening (e.g. with downstream manufacturers that need stable and clean sources of supply).
- Develop Canada's capacity to process raw materials into high-quality inputs for battery manufacturing, including the development of standards for green and responsible batteries.

Canadian ingenuity is already developing new technologies to process raw materials into create greener and higher-quality inputs for battery manufacturers. For example, one Canadian company has developed fifty patents for their process, which uses 75% less chemical reagents and emits 80% fewer GHG emissions than comparable processes used by processors abroad. These companies need support to access the financing required for large-scale demonstrations of these qualities, as well as support to generate market demand for cleaner inputs.

Governments can help by:

- Supporting the financing of large-scale demonstrations of green processing technologies
- Incentivizing investment by other actors into mining and battery metal processing
- Establishing new (or strengthening existing) research programs to support innovation in battery mineral processing
- Leading global efforts to develop a green certification/labeling initiative for battery manufacturing, in partnership with downstream manufacturers, retailers, civil society organizations and consumer groups
- Attract precursors, component and/or cell manufacturers to increase battery metal demand and anchor value-added mineral processing

Attract a Leading Battery Manufacturer to Invest in Canada

The presence of a leading global battery manufacturer would anchor Canada’s battery industry, supporting the growth of both upstream materials production and downstream development of electrified vehicle assembly and stationary storage technologies. Emerging pressure on companies to show environmental, social and governance responsibility by both investors and customers is an advantage to Canada.

Potential Actions

- Provide government-backed loans, grants, and other financial incentives to attract investment
- Partner with countries that are looking to collaborate on aspects of the supply chain beyond getting access to raw materials
- Promote Canada’s battery industry at global forums using the convening power of the Government of Canada to bring various segments of the value chain together
- Develop standards and regulations to ensure high quality, low-carbon batteries are required within advanced markets

Attract Mandates for the Production of Electrified Vehicles

Increasing the production of electrified vehicles would bolster Canada's automotive industry while fueling the growth of a domestic battery industry. In addition, our competitive advantages in agricultural, mining, aerospace, and marine transportation should be leveraged to establish Canada as a global leader in the electrification of broader transportation.

Potential Actions

- Address any competitive barrier for investment attraction into Canada.
- Leverage Canada's existing automotive industry to attract new mandates involving electrification; which support the development of battery production in Canada
- Re-/upskill autoworkers for the electrified vehicle industry
- Support the automotive supply industry in integrating into the North American electric vehicle market
- Convene stakeholders to develop a 'green stamp' or standard for batteries produced in Canada/North America that is attractive to down-stream users, particularly the automotive industry
- Commercialize and increase demand and use of 'Made in Canada' innovations in specialty battery markets, including aerospace; agriculture; mining; marine; and public transportation
- Support scale-up for Canadian companies in the specialty battery niche markets, including battery manufacturing systems, vehicle to grid integration and demand side management.

Establish Canada as a Global Leader in Stationary Energy Storage

The need to decentralize and increase variation in our power grids, along with our advanced battery research ecosystem can place Canada at the forefront of the stationary energy storage market, servicing domestic and export markets.

Potential Actions

- Increase demand through energy storage adoption incentives and targets, potentially through rebates and/or capital cost incentives at both the consumer and grid-level
- Work with provinces to harmonize market rules and ancillary services to support market participation (e.g. creating a market for behind-the-meter power being sold back to the grid or V2X applications)
- Update codes and standards to facilitate energy storage integration
- Develop an open source software for power sector participants to model the services/value that energy storage can provide as a means of developing an investment rationale

Own Battery Technologies of the Future including Recycling

Canada is at the forefront of development of next generation batteries and is punching above its weight in battery recycling. Competitive advantages in stationary storage and recycling should be leveraged to support the development of made in Canada intellectual property related to the next generation of batteries.

Potential Actions

- Research and development programs to generate the intellectual property that will build the next generation of battery technologies
- Accelerate battery recycling research to ensure Canada maintains its first mover advantage in North America
 - Undertake a comprehensive life-cycle analysis to assess the relative environmental footprints (carbon, water pollution, etc.), of existing recycling technologies in order to establish baseline data against which Canadian recycling contribution can be assessed (i.e. to lend credence to our claims to be 'greener')
 - Use its convening power to help industry consortia to form and pilot regional approaches (i.e. in North America) for used batteries
 - Reduce unnecessary regulatory barriers to enable cross-border/long-distance transport of batteries, without compromising protections for environment and public health
- Work with provinces, territories, and North American governments to harmonize regulations that underpin the battery recycling market