CANADA'S SEMICONDUCTOR COUNCIL

AUTOMOTIVE MICROCHIPS

WORKING GROUP REPORT

BRIDGING THE GAP IN CANADA'S EV SUPPLY CHAIN

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About Canada's Semiconductor Council

Canada's Semiconductor Council (CSC) is a national semiconductor industry organization representing a broad ecosystem of companies and institutions involved in the development and manufacturing of semiconductor components.

CSC is dedicated to accelerating the growth and development of Canada's semiconductor sector. The organization's goal is to strengthen our domestic supply chain resiliency and future in the digital economy by establishing Canada as a leader for semiconductor research, design and development, and manufacturing at the forefront of commercialization and innovation for the global semiconductor industry.

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CSC's Automotive Microchips Working Group

The Working Group convenes senior executives from the semiconductor and automotive sectors, alongside federal and provincial policy experts and representatives from the investment community. Its primary objective is to explore practical strategies to enhance the resilience of Canada's automotive microchip supply chain.

Executive Summary

The Electric Vehicle (EV) sector and its supply chain are critical to Canada’s economic and innovation activities. Semiconductors and power electronics play a central role in the EV industry, with estimates suggesting that up to $2,000 of an EV’s bill of materials will be semiconductors, and over 1,500 semiconductor components are found in a typical vehicle today.

While Canada’s semiconductor industry is well integrated into the global semiconductor market, projected to reach $1 trillion by 2030, its power electronics activities, specifically for EVs, remain limited. Although academic research in EV technologies is a Canadian strength, industrial R&D and commercialization using semiconductors and power electronics lag behind. In a limited capacity Canada is involved in activities at traditional automotive OEM suppliers, but much of the design and supply chain for critical EV components, such as traction inverters and battery electronics, is sourced from outside the country.

Canada’s R&D and commercialization efforts in power electronics for EVs are fragmented, presenting both economic and national security risks if a resilient, domestic supply chain is not developed. This is particularly important for adjacent critical sectors such as defense, aviation, energy generation and storage, which also rely on power electronics.

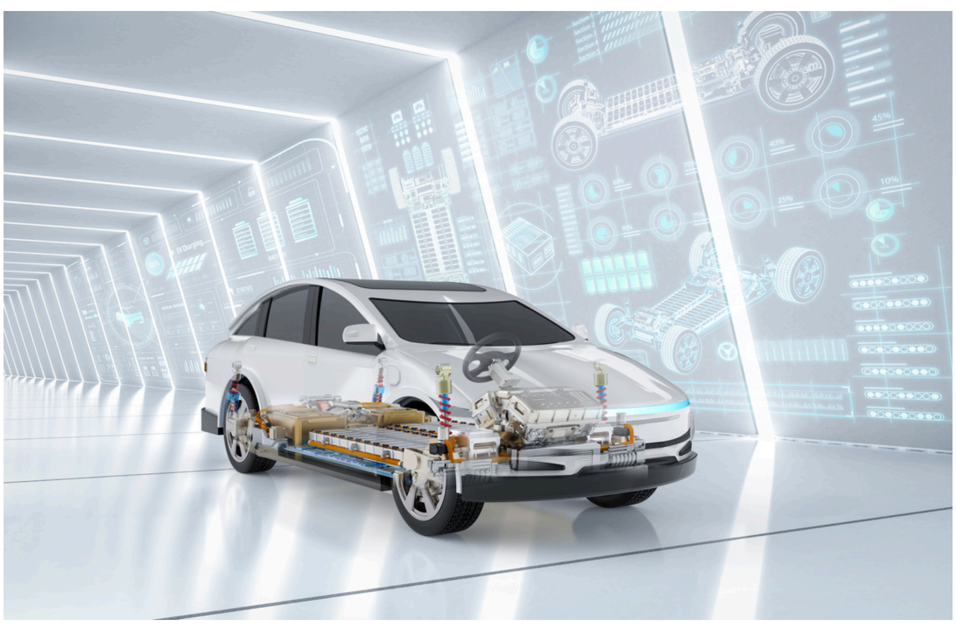
In response, Canada’s Semiconductor Council's Automotive Working Group is bringing together experts to analyze the EV landscape from a semiconductor perspective. Their findings will lead to recommendations aimed at enhancing Canada's EV content and strengthening its semiconductor capabilities in this fast-growing sector.

Introduction

Canada's investments in the final stages of the EV supply chain, particularly in vehicle assembly and EV batteries, are a significant statement to the ambition of Canada to be a leader in electric vehicles. However, these investments rely on a supply chain today that is almost entirely offshore. The growth of electric vehicles (EVs and hybrids, including PHEV and HEV), combined with increasing semiconductor content in every EV, requires a focused examination of Canada's semiconductor ecosystem and its substantial automotive assembly industry.

To address this, **Canada's Semiconductor Council established the Automotive Microchips Working Group to analyze the semiconductor supply chain for EVs in Canada,** identify opportunities to strengthen it, and define specific areas where government policy and investments in the semiconductor sector can address these vulnerabilities.

Note: Some research has already been conducted on Canada's Electric Vehicle (EV) ecosystem, notably by NGen (*Canadian Automotive Supplier Capability and EV Value Chain Analysis, 2022*) and Accelerate ZEV (*Canada's Battery Innovation Roadmap*). Additionally, countries like the UK have developed their own Power Electronics Roadmap. This report aims to serve as a foundation for creating Canada's Automotive Semiconductor Innovation Roadmap.



Methodology & Background Information

Climate change concerns and advancements in technology are driving the rapid growth of EVs in the automotive market. In some regional markets, such as China, over 50% of light vehicles sold now feature an electric drivetrain, either hybrid or full battery EV (Source: LMC Automotive).

As both commercial and consumer demand for enhanced functionality and convenience grows, the semiconductor Bill of Materials (BOM) and its value share in the automotive industry is growing rapidly.

The size of the automotive semiconductor market is growing fast—with projections **over US$100B by 2027** (Source: Techinsights, August 2024).

This growth trend is even sharper in the EV sector, since all electric vehicle engines require traction inverters and DC/DC converters, which use power semiconductors to transfer energy from the battery, and convert it to forward propulsion in the motor.

External charging infrastructure and on-board vehicle battery charging sub-systems also require significant semiconductor devices to enable the EV ecosystem to function. This growing trend can be seen in Figures 1 and 2 below.

FIGURE 1

BILL OF MATERIALS OF SEMICONDUCTOR COMPONENTS IN AN AUTO (Source: IFX, February 2024).

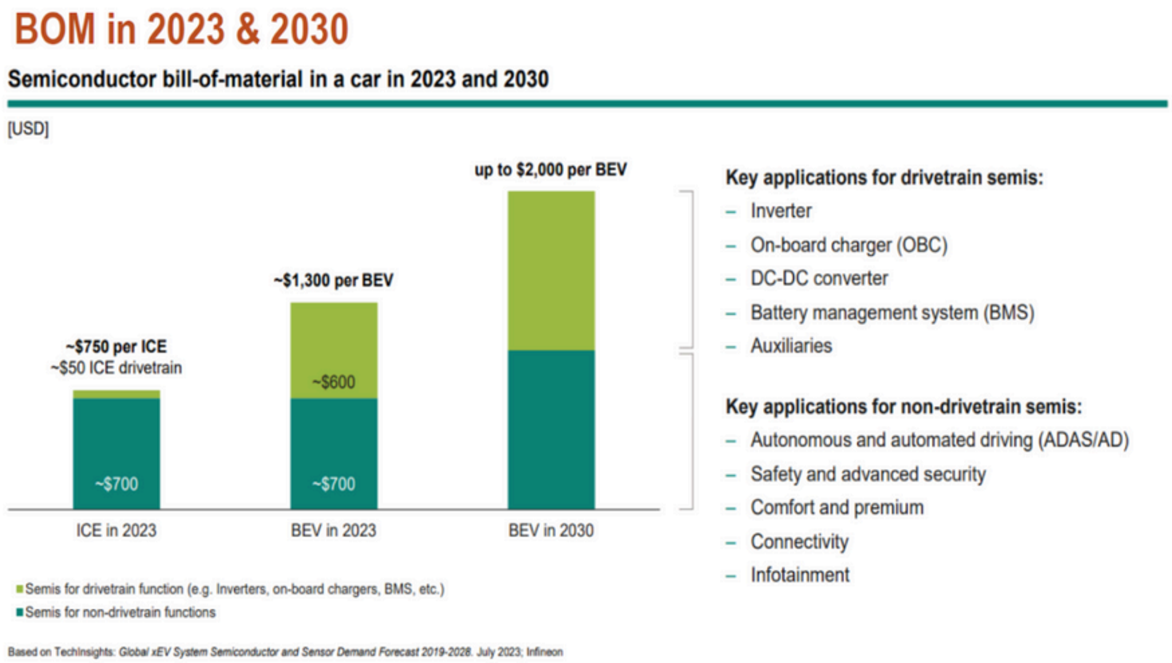
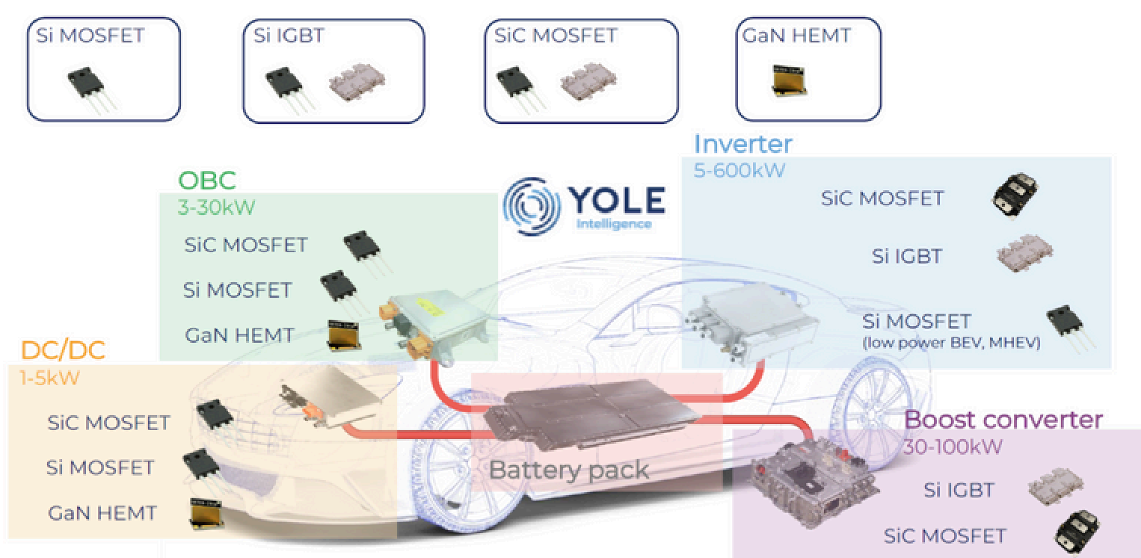


FIGURE 2

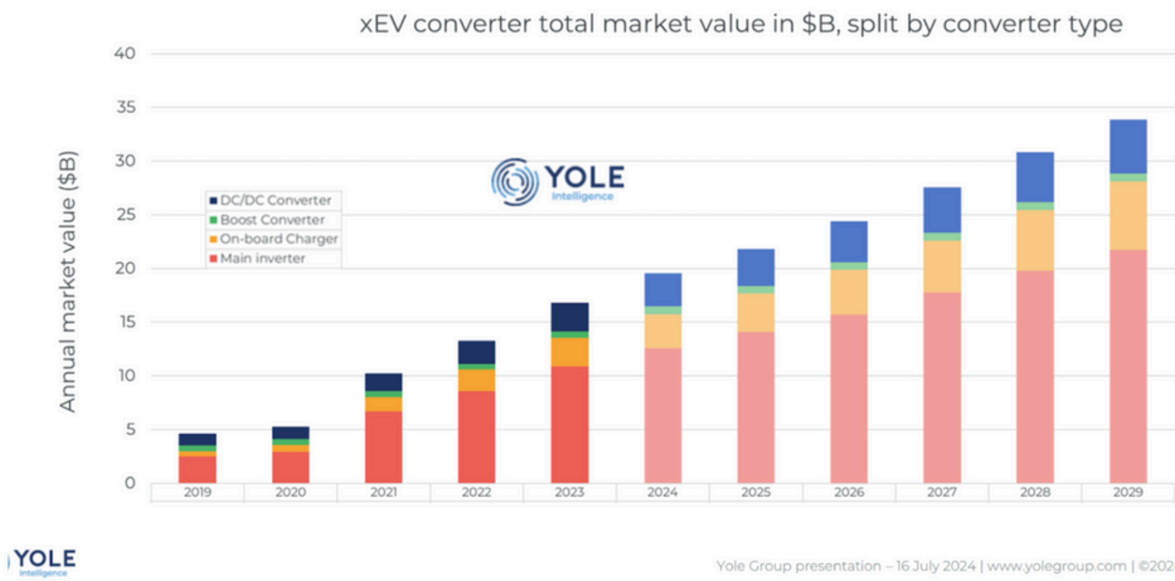
POWER ELECTRONICS IN xEV APPLICATIONS (Source: Yole Group, July 2024)



New power semiconductor devices are key to high growth in the EV converter market, which is projected to reach almost US$35B by 2029 (Figure 3). The traction inverter is the heart of an EV and represents the largest portion of the drivetrain's cost. Within the traction inverter, power semiconductors make up the majority of the subsystem's value.

FIGURE 3

xEV CONVERTER MARKET FORECAST IN $B - MAIN INVERTER IS TRACTION INVERTER

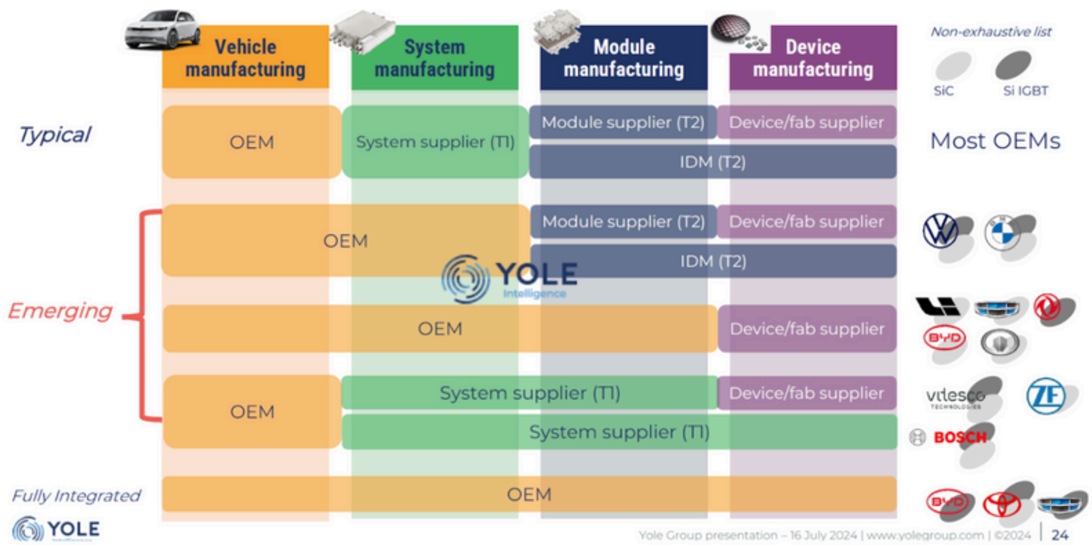


The power EV converter market has a large, complex supply chain that is rapidly transforming the entire automotive supply chain. Figure 4 outlines the enormous changes in the traction inverter supply chain that are impacting the entire automotive supply chain, creating both a risk and opportunity for local OEM automotive assembly regions.

The Canadian automotive sector, largely concentrated in southwestern Ontario, has achieved considerable visibility thanks to significant investments from both federal and provincial governments in new battery assembly and entire EV assembly by OEMs and Tier 1 suppliers.

FIGURE 4

RE-SHUFFLING OF DYNAMIC SUPPLY CHAIN FOR POWER ELECTRONICS

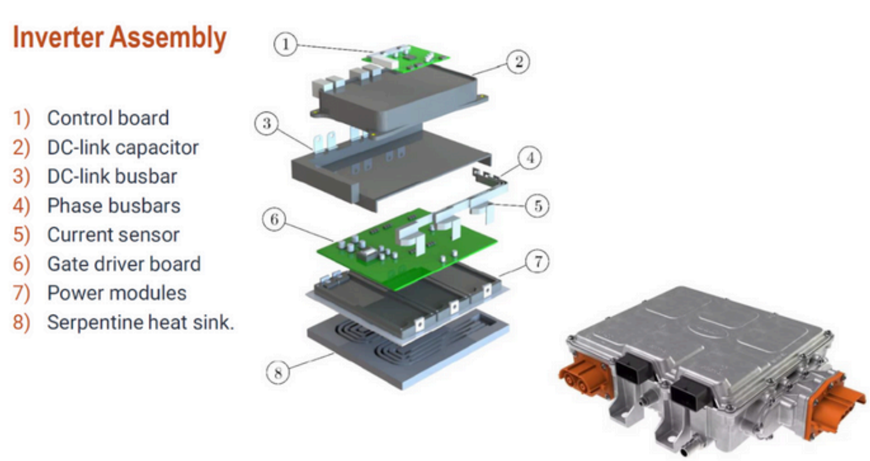


An EV traction inverter consists of many individual devices and assembly steps that connect it to the vehicle's power electronics. The complexity of the sub-assembly supply chain can be seen in Figures 4 and 5, illustrating the various devices within the traction inverter, and the assembly steps to build it.

The supply chain includes numerous sophisticated and complex design steps for thermal, mechanical, and electrical operations. Additionally, the manufacturing of traction inverters involves new materials and design steps that are not present in traditional combustion engine manufacturing.

FIGURE 5

COMPONENTS OF A TRACTION INVERTER



There is significant value in both design and assembly in the traction inverter supply chain. This includes the highly complex and rapidly changing power module portion of the supply chain that houses and connects the bare semiconductor power switch to the traction inverter final sub-system outlined in Figure 6.

By 2030, in some high performance electric vehicles, the **power semiconductor content may reach $1000/vehicle**—approximately 50% of the semiconductor BOM of $2000 (Figure 1.)

FIGURE 6

POWER MODULES FOR TRACTION INVERTERS WITH SILICON OR SIC DIE

As EVs change vehicle components, shifting from gasoline combustion engines to semiconductors that manage the flow of electric energy to the wheels, similar drastic changes occur in parallel in the EV supply chain, as illustrated in Figure 4. One major influence has been Tesla, whose approach to the automotive supply chain diverges from the traditional tiered supplier model used by legacy combustion engine automakers. Tesla works directly with software, semiconductor, and system suppliers, maintaining control over the entire EV supply chain. This disruptive model has introduced several supply chain options for automotive OEMs as they develop their EVs.

Figure 4 outlines five different options from the Tesla model (fully integrated) to thetraditional (typical) model, and various options in between.

The complexity of today's dynamic automotive supply chain presents significant challenges for Canada to strategically influence the EV supply chain. Additionally, there is a non-technical hurdle: the fragmented leadership and support across government and non-governmental groups.

While both federal and provincial governments are eager to grow Canada's EV supply chain, a unified, cohesive effort is essential for success. This includes coordinated development in power electronics, batteries, and other automotive technologies. Achieving this requires active collaboration across federal, provincial, and non-governmental organizations. Global competition is intense, and success is far from guaranteed. To overcome this, aligning resources, energy, and capabilities will be critical.

> “This is an opportunistic time for Canada to establish a presence in semiconductor manufacturing and packaging due to the increasing global demand for chips across industries like automotive, telecommunications, and renewable energy as the world shifts towards an electrified future. Geopolitical tensions, coupled with supply chain disruptions, have underscored the need for localized and secure semiconductor production. Canada's strategic location, coupled with its access to critical resources, a highly skilled workforce and robust manufacturing capabilities, positions it as a reliable North American hub. However, this must be treated as an urgent priority—investment in this sector is essential to securing Canada's economic competitiveness and guaranteeing a sustainable, technologically advanced future.”
>
> *Automotive Industry Leader, Nov. 2024*

Preliminary Findings

Canada's industrial sector has the competency and capabilities in advanced design and assembly to complete the EV supply chain based on the legacy Internal Combustion Engine (ICE) supply chain. However, there is currently minimal Canadian content in the entire EV supply chain.

FIGURE 7

GLOBAL SUPPLY CHAIN PLAYERS OF EV TRACTION INVERTERS

Canadian presence in the automotive power electronics supply chain is limited. Most of Canada's automotive supply chain is focused on servicing ICE components, or non-electronic components such as plastics and mechanical products.

The only Canadian company represented in Figure 7 is Magna, which is focused on power electronics, and connected to a joint venture with LG, driven mainly out of Korea. Yole Group, a global leader in market research, technology and strategic analysis has not identified any Canadian companies in the EV inverter supply chain.

Automotive EV Industrial Vulnerabilities: Perspective from the Semiconductor Ecosystem

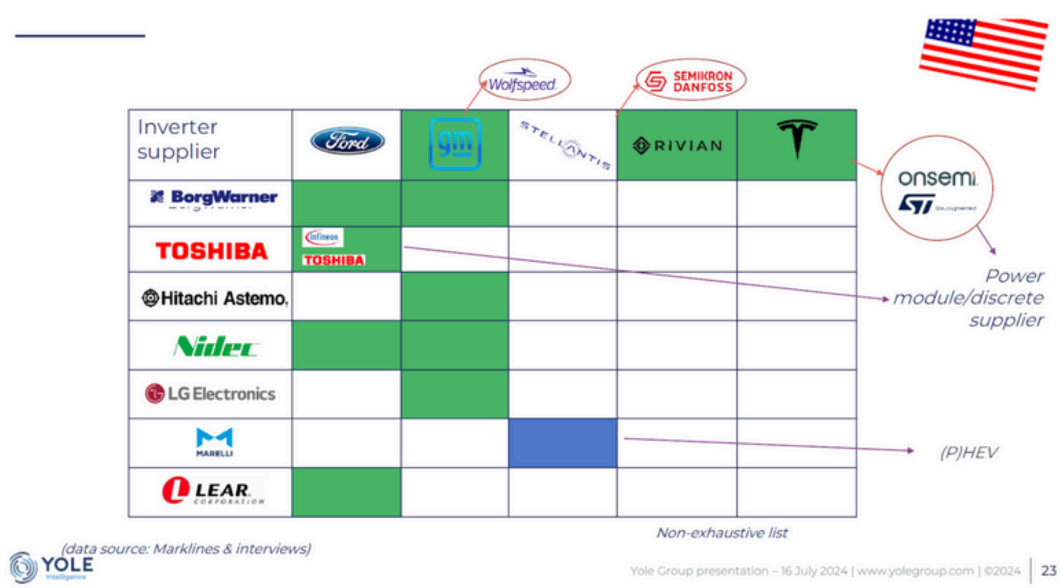
Lack of Domestic Companies in Automotive Semiconductor Sector

Semiconductor manufacturing, including materials targeting the automotive EV supply chain, semiconductor equipment and the manufacturing of semiconductor components—there is almost no presence in Canada.

Traction inverter design or manufacturing in the US supply—there is almost no presence in Canada as outlined by Yole Group (Figure 8). As Canada will be assembling a large percentage of the North American Electric Vehicles market, there is no reason why Canada cannot be a supplier of the traction inverter market with a focused and strategic effort to expand the commercialization of power electronics in Canada.

FIGURE 8

EXAMPLE - US SUPPLY CHAIN FOR EV TRACTION INVERTERS, 2023. ONLY 1 SUPPLIER IS NORTH AMERICAN BASED (RIVIAN AND TESLA MANUFACTURE THEMSELVES).



Semiconductor design, packaging, and electronics assembly—presence is limited in Canada.

- Infineon (Ottawa) – A German company, Infineon acquired GaN Systems, a member of CSC's Automotive Microchips Working Group.
- Dana (Oakville, Montréal) – An American company specializing in designing power and cooling systems for EV traction inverters and battery modules. Dana has a joint venture with Hydro-Québec, known as Dana/TM4, which develops inverters and electric motors for its customers.
- C-MAC Electronics Solutions (Québec) – A European company that designs and assembles non-power PCB electronics and sub-systems for global OEMs including Dana/TM4, and is a member of CSC's Automotive Microchips Working Group.
- Canadian startups – eLeap (Ontario) is developing traction inverters with design centers in Canada and China. EXRO (Calgary) is developing traction inverters with new technology and recently announced a collaboration with Stellantis .

Dependence on Foreign Suppliers and National Security Concerns

The EV supply chain in Canada is heavily reliant on foreign suppliers, with only the final stages of battery and EV assembly based domestically. This dependence extends to semiconductor components as well as the power modules and systems used in EV traction inverters, DC-DC converters, onboard chargers, and battery management systems.

Such dependence on foreign suppliers poses national economic security risks, particularly the threat of supply chain disruptions for automotive microchips. Given the increasing role and value of semiconductors in EVs, any interruption in the supply of semiconductors or subsystems like traction inverters or battery management ICs from foreign countries could result in a complete halt of Canada's EV production. This makes the EV supply chain highly vulnerable and in need of more resilient, domestic solutions.

Insufficient Industrial Research

While Canada excels in academic research related to semiconductors and electric motors for electric vehicles, there is a significant gap in its connection to the automotive industry within the country. The rapid evolution of the EV market is transforming the automotive supply chain, and industrial research is crucial for ensuring a smooth and efficient transition. Without strong industrial research leadership in Canada, academic research becomes limited, increasing the risk of both the supply chain and R&D for the commercialization of the automotive sector relocating outside the country. The loss of the automotive supply chain would have severe financial repercussions, particularly for the economy of Southwestern Ontario.

Previous examples in the Canada automotive ecosystem of industrial research for legacy combustion engines have existed, including Auto21 (University of Windsor hosted up to 2016) and groups connected to plastic mold making (now closed, Industrial Research and Development Institute of Midland, ON).

Vertical Integration of Ecosystems Outside of Canada and the North Eastern Corridor

The transition to electric vehicles has introduced new market entrants, such as Tesla and BYD, and has shifted the balance of power in the supply chain to new regions such as China. Today, with its rapidly growing EV market and supply chain capabilities, China is becoming vertically integrated, capable of producing nearly everything needed for EVs, including semiconductors, power electronics, batteries, and systems. This poses a significant competitive threat to both the Canadian and US car assembly manufacturing facilities. Developing a cross-border automotive semiconductor strategy, aligned with the automotive OEMs in Canada, is recommended by our Working Group to maintain Canada's position as a viable player in the global automotive manufacturing industry.

Opportunities to Build On Canadian Strengths

Strong Academic Footprint in Automotive Power

While Canada has limited capabilities in power electronics for the EV supply chain, Ontario has real strengths in academic research related to new mobility concepts, and basic research related to electric motors, battery technology, power electronics, new materials, and manufacturing technology. Unfortunately, much of this basic research remains disconnected from industrial R&D and commercialization activities in Canada.

In some cases, world-leading companies seek research support in Canada, but little of this commercial research stays in the country for manufacturing. Notably, there is no automotive industrial R&D centre that operates independently of a single proprietary company. Here are examples of world-leading academic centers for EV research in Canada, though not exhaustive.

- **McMaster Automotive Resource Center (MARC)**—a unique lab that connects academic research to industrial activities, with a base from many disciplines in McMaster such as Mechanical, Electrical and Computer Science. McMaster has specific industrial collaborations announced with Stellantis (Former FCA) and other industrial actors in electric motors.
- **University of Toronto**—strong power electronic and new semiconductor material design and prototyping, with direct applications in the automotive industry. The University of Toronto has industrial collaboration with Dana on power electronics cooling as an example.
- **University of Windsor**—Recently the University of Windsor has created the Charge lab, led by Dr. Narayan C. Kar, supporting both industrial and academic automotive electrification projects.
- **École de technologie supérieure (ÉTS)**—a leading institution in Quebec with strong expertise in applied research for power electronics, electric vehicles, and industrial applications.
- **Innovative Vehicle Institute (IVI)**—an applied research center based in Quebec, specializing in R&D, prototyping, and testing for innovative vehicle technologies, including electrification and power electronics.

There are numerous examples of individual projects at Canadian academic institutions, many of which operate under confidential NDAs in collaboration with companies outside of Canada. While valuable for advancing academic research, they may not necessarily contribute to Canada's broader goal of building a robust domestic EV commercialization and industrial ecosystem.

Canadian Adjacent Markets and Ecosystems

Beyond academic research, Canada has strengths in adjacent markets that can be leveraged for the automotive sector. Three key areas include: 1) the Bromont Semiconductor Manufacturing Ecosystem, 2) hydrogen fuel cells and vehicles, led by Ballard Power, and 3) the large digital semiconductor design talent ecosystem in the Greater Toronto Area, driven by fabless semiconductor companies such as AMD, Alphawave Semi, and Synopsys.

Bromont Semiconductor Manufacturing Ecosystem

Canada's non-academic semiconductor manufacturing ecosystem is primarily based in Bromont, Quebec, home to one of North America's largest semiconductor packaging facilities, operated by IBM Canada. Other key players in Bromont include Teledyne Dalsa, specializing in semiconductor sensors, and the C2MI industrial research institute, a not-for-profit organization supporting local companies in semiconductor R&D. While the Bromont ecosystem is not focused on power electronics, its technologies and expertise can be leveraged for future power electronics packaging R&D.

Hydrogen Fuel Cells and Vehicles

Canada has a long history of fuel cell R&D, most notably through Ballard Power in Vancouver. Fuel cell vehicles utilize power electronics and packaging technologies very similar to those in battery electric vehicles (BEVs). The major difference is that the electricity powering the motor is generated by a hydrogen fuel cell rather than a battery. As a result, technologies developed for BEVs can be leveraged for fuel cell vehicles, and vice versa.

Digital Semiconductor Design Talent Ecosystem in the GTA

Lastly, the growing talent ecosystem in Canada, which has attracted numerous multinational companies to establish large digital design centers for semiconductors, can be leveraged to advance power electronic systems. The expertise required to design semiconductor circuits for managing batteries and traction inverters necessitates deep system-level knowledge, critical for developing forward-leading specifications and ensuring efficient operations and integration into vehicles. The large ecosystem of talent in the Greater Toronto Area (GTA), with 5000 semiconductor professionals through CSC members alone, is a rich resource for providing this knowledge, either through engineering talent or partnerships with companies already embedded in the ecosystem.

Automotive Assembly Ecosystem and Legacy Automotive Footing

The most significant strength of Canada's automotive ecosystem in building a robust EV supply chain lies in Ontario's existing ICE car assembly operations and its existing supply chain in Canada. While many of these players specialize in legacy ICE technologies, the value of their relationships within the supply chain should be leveraged, and technical requirements for EV semiconductors could be shared to foster more robust and sustainable growth.

In addition to its legacy in combustion engines, Canada is home to a small but growing group of companies in electric bus and truck assembly, such as Lion Electric, Nova Bus, and New Flyer. These companies require power electronics for their products and can serve as key customers and collaborators in expanding Canada's power electronics ecosystem. The growth of electric buses, cars, trucks, and other vehicles in Canada is directly tied to advancements in power electronics and semiconductors

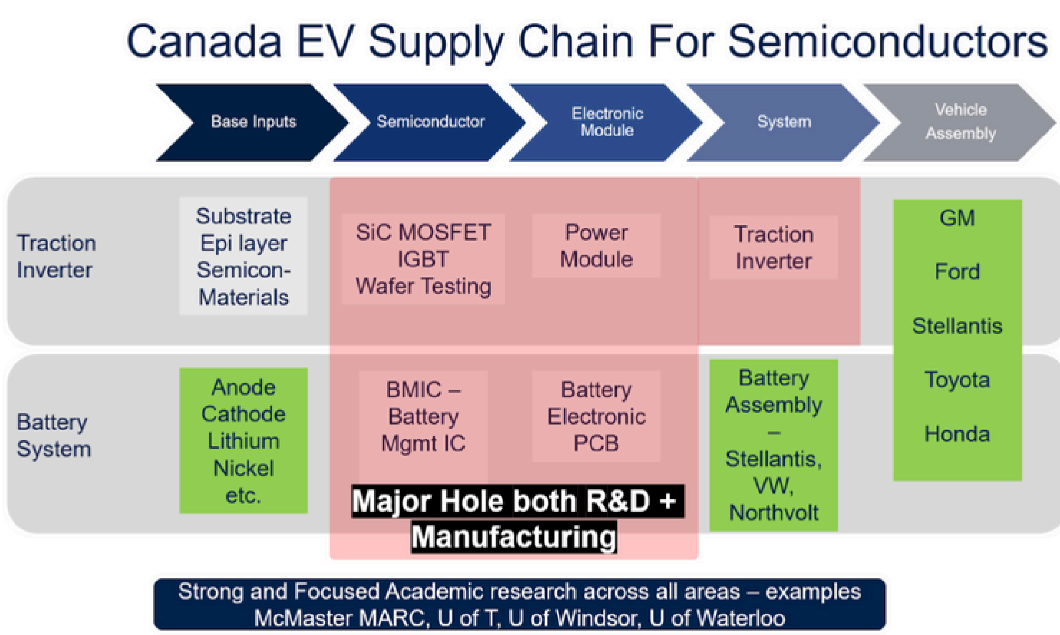
Recently, Ontario announced a collaboration with Mercedes-Benz to establish an Innovation Incubator at multiple locations across the province. This initiative exemplifies how existing strengths in the automotive supply chain can be leveraged to drive forward-looking innovation in the EV sector.

Recommendations

The image below highlights the gaps in Canada's EV supply chain, emphasizing the need for strategic investments, policy support, and collaboration to build a more resilient and self-sufficient supply chain for automotive semiconductors and power electronics in Canada.

FIGURE 9

SUMMARY OF CANADA'S EV TRACTION INVERTER AND BATTERY SYSTEM SUPPLY CHAIN STRENGTHS AND WEAKNESSES



Develop a Power Electronics R&D Funding Strategy and Plan Focused on Industrial R&D and Commercialization

We recommend that academic institutions, ICE automotive suppliers, OEMs, EV and battery assemblers collaborate with semiconductor companies and Canada's Semiconductor Council for further assessment and analysis. A national and regional strategy should be developed to transition the current supply chain towards EVs. Additionally, we propose strategically aligning the significant academic research in EVs with industry needs to create a robust regional supply chain for EV battery production and assembly in Canada. Two specific directions are recommended for the Canadian government to foster the development and growth of automotive power electronics.

1 Establish an Automotive and New Mobility Power Electronic Consortium

- **Collaboration with Industry and Academia:** The government should partner with industry stakeholders and academic institutions to create a Consortium focused on automotive power electronics packaging, and systems research, development and commercialization. This Consortium would be governed by local industry, ensuring that research priorities align with industry needs.
- **Core Research Team:** Academic researchers from various institutions would serve as core researchers, with leadership in research topics provided by local industry leaders. Financial support and governance would be sourced from industry partners.
- **Location and Infrastructure:** It is recommended that this Consortium be housed at a major university R&D hub with a strong focus on automotive electrification. An example of a suitable location is the industrial-focused McMaster Automotive Resource Centre (MARC) at McMaster Innovation Park. It has existing and upcoming university investments, prototyping and testing infrastructure, manufacturing expertise, and robust connections with major automotive OEMs and suppliers. It is important that the location is available for other leading university researchers to join.MARC has already established collaborative links with other leading universities in Southern Ontario with strong automotive resources valued by the industry.
- **Leveraging Financial Support:** Industry funding for the Consortium will be used to attract additional government funding. The proposed Consortium aims to complement semiconductor work by collaborating on the design, manufacture, and supply of critical components and software necessary for the mass production of power electronic systems. This includes control electronics, circuit components,

protection devices, connectors, busbars, semiconductor gate drivers, inductors, capacitors, sensors, thermal management solutions, packaging, and various mechanical parts.

> This model has been successfully implemented in Europe, with examples such as IMEC (Belgium), CEA-LETI (France), and the Fraunhofer Institute (Germany), where industry funds and governs research projects, with government support for program funding and talent development.

2 Targeted Funding for R&D Commercialization Projects

- **Creating a Knowledge Base:** The government should provide targeted funding for R&D projects aimed at developing a robust knowledge base in Canadian industry related to automotive power electronics and semiconductor applications for EVs. A significant portion of the value in the semiconductor market lies in the design, development, and marketing of semiconductor products, rather than in manufacturing alone.
- **Funding Mechanism Development:** It is requested that the various levels of government establish a funding mechanism specifically for R&D in automotive semiconductors and power electronics, extending beyond large investments in final EV battery and vehicle manufacturing. The key value for Canada resides in nurturing a knowledge and talent ecosystem that fosters job creation in R&D, rather than solely in manufacturing.

Develop a Canadian Semiconductor Manufacturing Strategy Integrated with Key Value-Added Local Manufacturing

While establishing automotive semiconductor manufacturing in Canada may be too ambitious as an initial step, it is essential to develop a long-term Automotive Semiconductor Manufacturing Strategy and supply chain within the country. This strategy should integrate both foreign and domestic suppliers into the automotive supply chain. No single country can independently supply all the semiconductor components required for future EVs. However, by partnering with other nations and leveraging their respective strengths, Canada can create a complete and well-defined EV supply chain.

Canada has the capability to manufacture critical components for essential EV subsystems, including traction inverters, DC-DC converters, batteries, and onboard chargers. To capitalize on these opportunities, particularly in areas like value-added power electronics packaging, targeted growth in both R&D and manufacturing should be prioritized. This may involve attracting foreign investments in critical technologies, as well as ensuring strong regulatory and policy support.

A coordinated regulatory and policy framework between Canada and U.S. entities, especially in the Great Lakes region, is essential for success. With the right cross-border policies in place, the Great Lakes Region has the potential to position itself as a global leader in EV research and manufacturing.

Next Steps

❯ Collaborate with industry stakeholders, consortia, and superclusters

Work directly with key players in the electric vehicle sector in Canada, such as Accelerate ZEV and NGEN, to create detailed roadmaps and actionable recommendations for developing the EV supply chain.

❯ Partner with leading Canadian academic institutions

Work directly with a research commercialization leader such as McMaster Automotive Resource Centre (MARC) and other automotive power electronics focused universities to establish an Industrial Automotive Power Electronics Packaging and Systems R&D Consortium.

❯ Foster collaboration with established international companies

Bring together international automotive semiconductor companies with local suppliers of automotive systems and components to increase the Canadian content of power electronics in future EVs in Canada.

Appendix: Acknowledgements

This report was **authored by Kirk Ouellette, VP of Global Strategy at STMicroelectronics, and Chair of Canada's Semiconductor Council's Automotive Microchips Working Group**. We would like to express our gratitude for the valuable contributions from the Working Group members listed below, and other contributors who supported this effort. Their expertise and insights have been instrumental in shaping the findings and recommendations in this report.

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- Gordon Harling, CEO, CMC Microsystems
- David Adams, President, Global Automakers of Canada
- Greg Overwater, Senior Director – Safety, Innovation and Regulation, Global Automakers of Canada
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