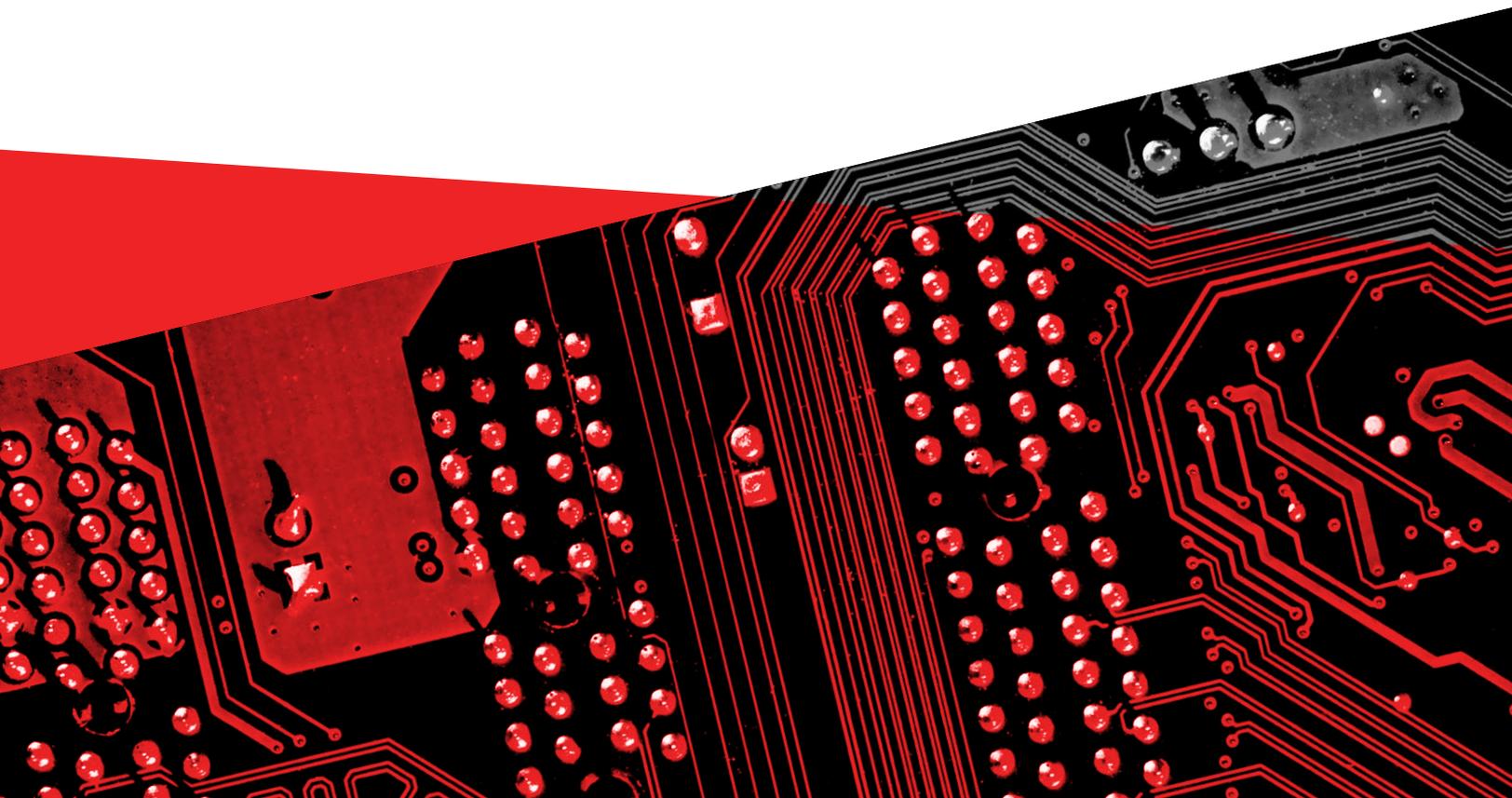


CANADA'S
SEMICONDUCTOR
COUNCIL™

Roadmap to 2050: Canada's Semiconductor Action Plan

Industry Report & Recommendations
November 2021





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Abstract

The purpose of this report is to provide data-driven insights in support of a national semiconductor strategy and action plan to fuel Canada's economic recovery, and to provide an overview of the current state of Canada's semiconductor industry.

Primary data-driven insights and perspectives from [stakeholders](#) across this industry have been summarized in this report, and alongside comprehensive research and analysis, were used to generate a National Semiconductor Action Plan that positions Canada to be a global developer, manufacturer, and supplier of semiconductor products that are embedded in electric vehicles, medical devices, consumer electronics, and precision agriculture.

This final action plan and report is issued by [Canada's Semiconductor Council](#).

For details about [the Council](#), and the [stakeholder engagement process](#), refer to the appendices of this report.



Recommendations

	SHORT TERM (2021-25)	MEDIUM TERM (2021-35)	LONG TERM (2021-50)
STRENGTHEN AND DIVERSIFY THE SUPPLY CHAIN	1.1 Establish a Canadian consortium of cross-industry semiconductor buyer	1.2 Leverage semiconductor demand from key Canadian sectors to stimulate domestic chip production	
DEVELOP ONSHORE MANUFACTURING	2.1 Develop a sustainable business model for fabrication in Canada 2.2 Attract multinational semiconductor companies to Canada		2.3 Leverage Canada's talent in research and development to disrupt and innovate the current semiconductor fabrication process
ESTABLISH A UNIQUE SPECIALIZATION AND BRAND FOR CANADA	3.1 Increase incentives and support for Canadian semiconductor research and design 3.2 Invest in electric vehicle R&D and leverage Canada's strengths to develop a domestic supply chain 3.3 Invest in sensor R&D, design and manufacturing	3.4 Invest in higher education grants to empower our best and brightest to pursue R&D in essential chip technologies and to remain in Canada 3.5 Invest in increasing testing and manufacturing capacity for sensors at scale 3.6 Develop higher education programs for sensor design	3.7 Invest in building a global brand trumpeting Canada's specialization within the semiconductor space
FOSTER INNOVATION AND SUPPORT MARKET DEVELOPMENT	4.1 Increase investment in domestic companies that are designing and developing AI- and quantum-enabled chips 4.2 Protect domestic Intellectual Property, and support its growth and commercialization 4.3 Enhance investment opportunities to fill a major gap in access to patient capital 4.4 Launch targeted innovation programs around chip enabled technology within higher ed institutions 4.5 Incubate and support made-in-Canada entrepreneurial ventures in the semiconductor industry 4.6 Establish the federal government as a primary semiconductor customer for Canadian chip technology	4.7 Recruit high profile international experts to pursue research and development around next generation chips and flexible fabrication	4.8 Foster a diverse talent pipeline between higher education and the semiconductor industry

Executive Summary

Semiconductors are [ubiquitous, cornerstone components](#) of nearly every aspect of our tech-enabled lives. They require significant investment and resources to manufacture, and take years to develop and months to produce. However, the global semiconductor sector is being impacted by nationalism, supply chain models that focus on low production costs over resiliency, and lingering COVID-19 disruptions. With this in mind, the recent chip shortage making headlines around the world represents a significant danger for Canada.

Semiconductor supply — which has long focused on concentrated, large scale manufacturing over a more diversified approach — is being near-shored, reshored, and restructured to the advantage of [countries with dominant positions](#), including the U.S., Taiwan, South Korea, the UK, France, Germany, and China. Increasingly, Canada is being left on the outside, looking in. Meanwhile, demand for chips continues to rise, putting Canadian production at risk until a reliable supply of semiconductors can be sourced. **Canada needs a semiconductor strategy to deal with these twin shocks to supply and demand.**

“Countries like China, South Korea, and the US view advanced semiconductors as fundamental to national security. The potential crisis for Canada is a situation where semiconductors become a national security issue. From a manufacturing perspective, we have minimal infrastructure to support that.”
- Ron Glibbery, CEO and Founder, Peraso

Canada's key industries are heavily dependent on global semiconductor supply chains that have proven to be volatile and vulnerable. The value chain is [currently concentrated](#) in six major regions: the U.S., South Korea, Japan, mainland China, Taiwan, and Europe.

Additional background information about [semiconductors](#), and the [global value chain](#), is available in the appendices of this report.

As noted in *Strengthening the Global Semiconductor Supply Chain in an Uncertain Era*, an April 2021 report from Boston Consulting Group and the Semiconductor Industry Association:

About 75% of semiconductor manufacturing capacity, as well as many suppliers of key materials — such as silicon wafers, photoresist, and other specialty chemicals — are concentrated in China and East Asia, a region significantly exposed to high seismic activity and geopolitical tensions. Furthermore, all of the world's most advanced semiconductor manufacturing capacity — in nodes below 10 nanometers — is currently located in South Korea (8%) and Taiwan (92%) [editor's note: Intel has since developed



a 7 nanometer process]. *These are single points of failure that could be disrupted by natural disasters, infrastructure shutdowns, or international conflicts, and may cause severe interruptions in the supply of chips¹.*

Canadians are increasingly clear eyed about China's intention to control supply chains, and the increasingly isolationist stance of the U.S. They know that sovereignty, along with sufficiency, are of the utmost importance. With this in mind, elected leaders must take the next step in establishing guidelines and protections for the semiconductor sector. We need a national strategy to keep IP in Canada, and also to ensure the resiliency of our supply chain.

Canada's [semiconductor industry](#) has little market share compared to countries that established fabrication and R&D capacity early on, but ensuring robust access to semiconductors is crucial from a national security standpoint, as critical technologies, consumer products, and [employment opportunities](#) rely on chips.

"If you look at Korea or Israel, there is a very clear pathway to commercialization and that pathway to commercialization starts locally. I don't think anybody in Canada who has produced a chip has ever been able to sell to any of the large Canadian players, whether it's the military, telecommunications firms, or any of those. If you can create a market locally, you can create more money coming in from the venture capitalists. You can drive entire ecosystems."
- Sally Daub, CEO and Founder, ViXS

In addition, climate change has had a profound impact on the global semiconductor industry. For example, in 2021, drought in Taiwan and extreme cold weather in Texas placed strain on semiconductor supply. In an August 2021 *Globe and Mail* article, experts noted that semiconductors are almost exclusively manufactured in regions at high risk for natural disasters². This includes Taiwan Semiconductor Manufacturing Corporation (TSMC), which is the largest independent manufacturer of chips with the vast majority of its fabrication operations in Taiwan — a region prone to damaging typhoons as well as seismic activity³ — but it has made strategic investments in the US and other regions to diversify its manufacturing base.

"If there's ever going to be an opportunity for change, now is the time. And if we don't push for it, Canada will always be in big brother's shadow."
- Tony Pialis, CEO and Founder, Alphawave

¹

https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

² <https://www.theglobeandmail.com/business/article-experts-saw-the-computer-chip-shortage-coming-now-theyre-calling-on/>

³ <https://www.eetasia.com/18020702-blog-earthquakes-and-semiconductors/>



What's more, the COVID-19 pandemic led to increased demand for chips to power online learning, virtual healthcare, and working from home⁴. Manufacturers of those chips filled orders from companies who wanted to secure supply — in particular, companies who design consumer electronics like mobile phones, tablets, and gaming consoles. At the same time, those types of chips required the most advanced manufacturing technologies and there are only a few semiconductor manufacturers who have such capability. New semiconductor fabrication plants take years to plan, design, construct, and launch,⁵ which puts a limit on the manufacturing capacity. The supply bottlenecks for chips (and constraints in other segments of the supply chain for advanced devices), combined with a strong demand, produced a domino effect across multiple industries, sectors, and geographies.

Additional data about recent trends impacting the semiconductor supply chain can be found in the appendices of this report.

As global demand for chips is expected to continue rising, total global fabrication capacity will need to increase. As the Semiconductor Industry Association reports, “The global semiconductor industry is planning accordingly to meet this projected market growth in the years ahead, through record levels of investment in manufacturing and R&D.”⁶ Supply chain vulnerabilities and geopolitical instabilities revealed by the COVID-19 pandemic poses significant risks to Canada's key industries. Building domestic manufacturing capability and increasing supply chain resilience should be an area of focus. Efforts should also be directed towards improving talent pipelines to ensure that the industry can keep up its pace of innovation⁷. Failure to sustain or develop components of the semiconductor supply chain in Canada could result in disastrous implications as hundreds of other sectors depend on semiconductors or semiconductor-related products.

**“If you categorize industries, whether it's consumer, communications, automotive, computing, or fintech and look at what's foundational to it, it is the ability to move data around, access data and analyze the data. If you peel that onion back even further, for that to happen effectively, you need the ability to process the communication and that data. And it's no surprise to anybody that, to do that, you need semiconductors.”
- Jim Seto, CEO, ePIC Blockchain; past Corporate VP, Foundry Operations, AMD**

⁴

<https://www.semiconductors.org/wp-content/uploads/2021/06/SIA-Final-submission-to-FCC-on-Impact-of-Global-Semiconductor-Shortage-on-the-US-Communications-Sector-June-10-2021.pdf>

⁵ Ibid.

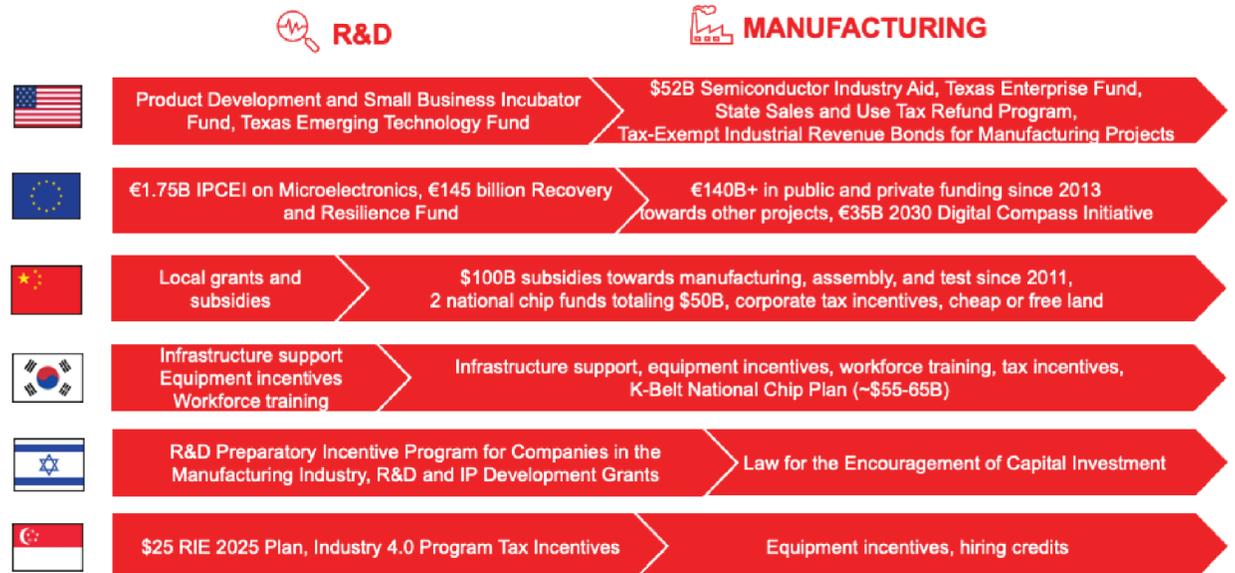
⁶

<https://www.semiconductors.org/chipmakers-are-ramping-up-production-to-address-semiconductor-shortage-heres-why-that-takes-time/>

⁷

<https://www.semiconductors.org/chipmakers-are-ramping-up-production-to-address-semiconductor-shortage-heres-why-that-takes-time/>

Major Global Semiconductor Incentives & Policy in R&D vs. Manufacturing



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<https://www.forbes.com/sites/startupnationcentral/2019/09/24/the-shared-tech-roots-of-silicon-valley-and-israels-startup-nation/?sh=332258ed6f3d>

Virtually every industry and workplace in the public and private sectors, including automotive, mining, transportation, cybersecurity, finance, retail, education, and many more, rely heavily on semiconductors to power electronic devices, technology, or machinery required to run businesses. These sectors rely heavily on the development of chips to advance technologies or



research and development. For example, most innovations in the automotive sector are coming from electronics rather than mechanics, with electronics systems projected to account for 50% of the total cost of the average car in 2030, compared to 22% of the total cost in 2000⁸.

“Tomorrow’s hyperconnected economy is paved with significant growth prospects – from advanced manufacturing, smart cities, digital health, autonomous transportation to clean energy and technology are all predicated on a semiconductor-rich foundation. We need to reflect as a nation on the best strategic options to foster a strong domestic semiconductor supply to support the growth of the digital-led economy in Canada.”
- Namir Anani, President & CEO, Information and Communications Technology Council

Canada’s leadership as part of the global semiconductor industry is key to both the short- and long-term viability and sustainability of [several critical economic sectors](#) for Canada, including but not limited to automotive, clean energy, and health. In relation to the Canada-U.S. Critical Minerals Action plan, semiconductors power the machinery required to process rare minerals for battery production, as well as account for a significant percentage of the cost of traditional and electric vehicles. Many of the federal greening government strategy goals, such as decarbonization goals, climate change priorities, and the manufacture of zero-emission vehicles, require technological advancements. This, in turn, requires semiconductors to be embedded into many of the products needed to achieve these targets. Finally, to ensure preparedness for globally disruptive events (e.g. pandemics), a resilient and reliable supply of domestic semiconductors will be necessary to manufacture essential medical equipment and supplies, and support domestic vaccine production.

Sector-by-sector [analyses](#) can be found in the appendices of this report.

Canada’s semiconductor industry lags behind global leaders like Taiwan, Israel, and the U.S. — particularly in terms of facilities set up to manufacture chips on a large scale. However, it has enormous growth potential, thanks to high global demand for Canadian-trained STEM talent, a strong foundation in research, innovation, and design, and access to raw materials critical to electronics production.

“The only way you’re going to get students wanting to come in and work in the semiconductor area is if they see successful companies in that place. I don’t think it makes sense to try to drive more students coming out [of school] into semiconductor companies, unless we’re confident that we can create a pathway for these successful companies.”
- Sally Daub, CEO and Founder, ViXS

⁸ <https://www2.deloitte.com/tw/en/pages/technology-media-and-telecommunications/articles/semiconductor-next-wave.html>



A strong and resilient Canadian semiconductor industry will enable Canada to adopt a more nimble approach to managing a shifting international relations landscape, better absorb supply chain fluctuations, and be a leader in transformative areas like quantum, artificial intelligence, clean tech, and beyond. Such an effort requires commitment and resources across all sectors, including government, private industry, academia, and not-for-profits.

Canada needs to leverage its strengths, declare its unique differentiation, and consciously develop an ecosystem that supports this specialization. It also needs to empower top talent in the semiconductor sector through bold investments in emerging technologies, and build a global brand for the nation as a hub of research and design innovation.

This Action Plan makes recommendations focused on four overarching goals:

- 1. Strengthen and Diversify the Supply Chain**
- 2. Develop Onshore Manufacturing**
- 3. Establish a Unique Specialization and Brand for Canada**
- 4. Foster Innovation and Support Market Development**

The recommendations contained in this Action Plan, and its accompanying research, are based on engagement with over 100 stakeholders across Canada. Together, they represent a roadmap to address an urgent need, and also take a leapfrog approach that positions Canada as a global leader in the semiconductor industry. A robust semiconductor strategy, properly implemented and resourced, has the potential to generate a wealth of economic and employment opportunities, provide domestic solutions to address vital supply chain needs, and support a huge array of businesses and service providers.



1. Strengthen and Diversify the Supply Chain

There is an immediate and pressing need for semiconductors that is impacting production (and by extension, employment) nationwide.

“There is a great concern that the lack of chip availability could at some point start to threaten the health care that medical technology companies can provide. It challenges us with the leading edge of our business, which is new products.”
- Neil Fraser, Medtronic

In response, Canada must take a unified approach to securing a steady supply of semiconductors that sees companies and industries come together to buy chips from international partners and establish a case for increasing domestic production.

“As businesses around the globe and life in general, transform digitally, the semiconductor industry and its global supply chains have impacted every sector. Canada is blessed with natural resources for materials, as well as superior thought leadership and IP. Manufacturing drives further innovation and Canada should be investing in domestic foundries, labs and bleeding edge chip technologies. It’s time for Canada to step up and invest in this critical sector.”
— Angela Mondou, President & CEO, TECHNATION

Actions to strengthen Canada’s semiconductor supply chain benefit consumer confidence and represent an important national security measure; a reliable chip supply backstops upstream and downstream industries vital to the Canadian economy.

SHORT TERM (2021-2025)

1.1 Establish a Canadian consortium of cross-industry semiconductor buyers

Given the lack of large-scale semiconductor fabrication in Canada, and the time and resources required to establish these facilities, Canadian companies in need of chips must continue to seek offshore supply. We therefore recommend the creation of a government-led consortium of buyers that can establish a strong negotiating position through high volume purchases of semiconductors produced by international suppliers.



There is an opportunity to bring together companies from different industry verticals; including auto, consumer appliances, robotics et al. to negotiate front-of-the-line supply from overseas chip manufacturers. Being able to forecast demand in advance is essential for success; working to outline specific needs 18-24 months beforehand and bringing together leaders who make purchasing decisions for assembly in Canada to make commitments. The consortium requires strong leadership, a shared vision amongst industry partners, and contractual agreements to purchase negotiated supply.

The Canadian government can support the initiative through trade relations, fostering introductions, and negotiating deals on behalf of Canadian companies in the consortium.

MEDIUM TERM (2021-2035)

1.2 Leverage semiconductor demand from key Canadian sectors to stimulate domestic chip production

In order to build a case for increased domestic fabrication of semiconductors in high demand, we recommend engaging with anchor companies doing business in auto manufacturing, energy, home appliance manufacturing, and telecommunications — including Bombardier, Clearpath Robotics, Danby, Linamar, Miovision, and Telestat. Their input into forecasted demand can be leveraged to drive onshore production of semiconductors — by optimizing existing fabrication (“fab”) facilities, attracting a multinational semiconductor manufacturer to Canada, and/or constructing a net-new large-scale fab.

The majority of semiconductors used in these sectors today are in extremely short supply globally⁹, as most major foundries commit to advanced technologies in demand by consumer electronics manufacturers. However, the demand for these chips from these industries is likely to remain steady, and with that in mind, there is an urgent need to address the shortage by increasing the production of these semiconductors. We recommend pursuing a new fabrication opportunity in Canada; a partnership with a major manufacturer represents a strategic opportunity that, with matching funds from the federal government, could lead to a trade negotiation to allocate and guarantee supply of vital chips for companies in these sectors operating in Canada.

⁹ <https://semiengineering.com/200mm-demand-surges/>



Auto Manufacturing

Domestic semiconductor innovation and manufacturing is key to the long-term sustainability of Canada's auto sector, which creates over 500,000 direct and indirect jobs¹⁰, and accounts for nearly \$80 billion worth of exports¹¹. With the majority of innovations in the automotive sector coming from electronics rather than mechanics, electronics systems are projected to account for 50% of the total cost of the average car in 2030¹².

“The biggest challenge that we have in Canada is the actual users of semiconductors for the automotive industry are typically tier one or even tier two, tier three suppliers, and they're not located here.”

- Scott MacKenzie, Senior National Manager, External Affairs, Toyota Motor Manufacturing Canada

Producing semiconductors in service of the auto industry meets a uniquely steady demand. According to a 2019 U.S. International Trade Commission report:

Because of the long qualification time and high quality expected, demand for automotive chips is more “sticky” than standard consumer electronic chips. In general, auto OEMs maintain the same sourcing throughout the model run of a vehicle (approximately 5 years) and consider new suppliers only when they are launching new models. Auto OEMs are likely to be repeat customers of companies and brands that they have previously qualified both for use in existing vehicles as well as future models, given the expectation that the supplier supports their product for the lifetime of a given vehicle.¹³

In addition, the cost for building manufacturing capacity to support demand for the kinds of chips the auto industry requires is much lower than the most advanced technologies. The EU €1 billion Bosch is investing in a new semiconductor fabrication facility in Dresden, focused on producing larger chips in support of automotive manufacturing, is significantly less than what is required to produce much smaller semiconductors¹⁴. A similar facility in Canada would be a boon to our country's auto industry, and could also create other non-auto sector chips to provide domestic chip manufacturing capacity in Canada.

¹⁰ <https://www.cvma.ca/industry/facts/>

¹¹ <https://www.theglobeandmail.com/world/us-politics/article-trudeau-trump-trade-meltdown-to-threaten-80-billion-in-canadian-auto/>

¹² <https://www2.deloitte.com/tw/en/pages/technology-media-and-telecommunications/articles/semiconductor-next-wave.html>

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¹⁴ <https://www.bosch.com/stories/bosch-chip-factory-dresden/>



Energy

Semiconductors play a key role in clean energy, serving as the basis for solar electric energy systems, wind turbines, and other electric equipment used in the renewable energy supply chain. Semiconductors are also becoming increasingly important in making the electric grid more intelligent through the use of smart meters, sensors, wireless communications, and control systems. The use of semiconductors in clean tech is crucial to Canada's transition to a low-emission economy. As the Consulate General of Canada in Boston recently noted, Canada is committed to "collaborating with stakeholders and jurisdictions across the country and around the world to bring innovative and competitive clean technology to market."¹⁵

Home Appliances and Consumer Electronics

Semiconductors power virtually every modern-day technology and product, including and especially consumer electronics. In addition, IoT-enabled home appliances rely on increasingly sophisticated chips to perform automation and communication functions.

In 2020, the Computer and Electronic Product Manufacturing sector employed 53,295 workers and the Electrical Equipment, Appliance and Component Manufacturing sector employed 34,370. Together, they make up 6% of manufacturing jobs in Canada. Consumer electronics and home appliances wholesale and retail employ an additional 78,055 Canadians¹⁶. Revenue in Canada's Consumer Electronics sector is projected to reach USD \$7.343 billion in 2021, with an anticipated compound annual growth rate (CAGR) of 4% by 2025¹⁷.

Telecommunications & Satellite Technology

Semiconductors play a critical role in innovations in telecommunications technology, including 5G and satellite communications. The global mobile industry is now upgrading to 5G technologies. GSMA has estimated 5G to deliver approximately an additional CAD \$190 billion to the Canadian economy for the entire period 2020–2040¹⁸. While 4G remains the dominant technology in Canada currently, 5G adoption will begin to accelerate from 2021 and will achieve more than 40% of connections by 2025. Top Canadian mobile service providers, including Rogers, Bell, and Telus, have all launched commercial deployment of 5G and established state-of-the-art research centres in collaboration with academic institutions and local governments.

¹⁵ <https://greentownlabs.com/partners/partner/the-consulate-general-of-canada-in-boston/>

¹⁶ <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610048901>

¹⁷ <https://www.statista.com/outlook/dmo/e-commerce/electronics-media/consumer-electronics/canada>

¹⁸ <https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=54165916&file=051120-5G-in-Canada.pdf>

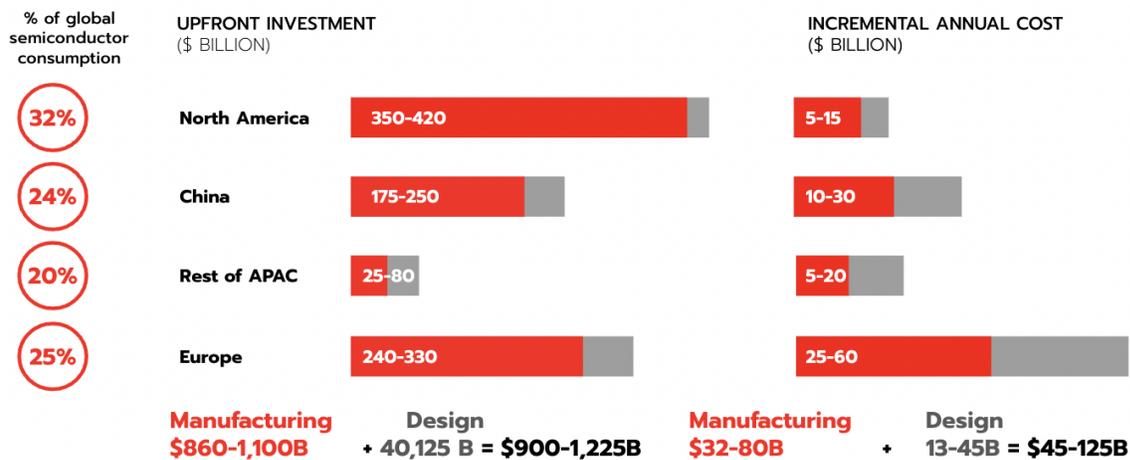


2. Develop Onshore Manufacturing

“Nations like the UK, US, and the EU are all committing dollars now to bringing silicon manufacturing production on-shore so that they have control of at least part of their supply chain. There's not a peep coming out of Canada on this. It's a barrier.”
 - Tony Pialis, Co-Founder and CEO, Alphawave

Semiconductor fabrication is a cost prohibitive and time consuming endeavour. However, given the steadily rising demand for semiconductors worldwide, projects to establish large-scale manufacturing domestically would yield enormous benefit within Canada and internationally.

Incremental Cost to Cover 2019 Demand with Fully “Self-Sufficient” Localized Semiconductor Supply Chains



SOURCE: Boston Consulting Group & Semiconductor Industry Association.
https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

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To achieve this, we recommend a three pronged approach, focused on surfacing a forecast of the semiconductors with the highest demand across key Canadian industries and developing a business model for fabricating these chips; leveraging Canada’s environmental and political stability and international partnerships to attract multinational semiconductor fabrication partnerships; and seeding innovation by Canadian engineering talent to disrupt the fabrication process altogether and pioneer a more flexible approach to manufacturing semiconductors.

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https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf



SHORT TERM (2021-2025)

2.1 Develop a sustainable business model for fabrication in Canada

“If we build manufacturing capability on-shore, it will create a whole ecosystem around it — we need to be willing to take a stand on our own to guarantee our own supply chain. If you look at vaccine manufacturing and distribution as an example, Canada was low on the priority list for other nations; if there is a shortage of semiconductors, why would we think there would be any difference?”

- Tony Pialis, Co-Founder and CEO, Alphawave

Semiconductor fabrication facilities (or “fabs”) are expensive: advanced analog fabs require USD \$5 billion in land, equipment, and materials; and for advanced logic and memory fabs, the price tag can reach USD \$20 billion.²⁰ The cost of building a fab increases with its technological advancement and capability. The economic and industrial impacts of fabs are also significant. Each new fab built in the US is estimated to create 110,000 temporary jobs during the build-out and 4,200 permanent jobs in semiconductors, not to mention the positive effects on downstream industries like consumer electronics, medical devices, auto, and clean energy²¹.

Throughout the world, global manufacturers like TSMC, Samsung, and Intel, are looking to build new sites²². Since fabrication is highly capital intensive, “the availability of attractive investment conditions — particularly government incentives — and access to robust infrastructure (power and water supply, transportation and logistics) and a skilled manufacturing workforce at competitive rates have traditionally been the key success factors”²³. Along with synergy with existing footprints and ecosystems and protection of IP, they make up the criteria companies look to when selecting locations for new facilities.

Canada possesses many of these characteristics to be an appealing destination for global foundries, with its strong talent base, large water supply, advanced infrastructure, and historically bustling ecosystem. However, more targeted and robust government incentives and

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<https://web-assets.bcg.com/9d/64/367c63094411b6e9e1407bec0dcc/bcgxsia-strengthening-the-global-semiconductor-value-chain-april-2021.pdf>

²¹ https://www.semiconductors.org/wp-content/uploads/2021/05/SIA-Impact_May2021-FINAL-May-19-2021_2.pdf

²² Examples include TSMC in Arizona, Intel in Arizona and Israel, Samsung in Texas.

²³

https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf



policies are necessary to attract leading companies to Canada and foster a vibrant domestic ecosystem and robust supply chain.

Currently, government incentives in Asia support the region's leadership in initiatives requiring intense capital; the U.S., meanwhile, uses its tendency to attract top talent to rise to the top in R&D. High geographic concentration of semiconductor manufacturing capacity poses threats to the resilience of the global supply chain²⁴. Action to align with emerging industry trends is required for Canada to address future semiconductor demand and avoid additional shortages. Ensuring a steady supply of semiconductors is especially important in light of ongoing geopolitical instability, and increasingly vulnerable environmental conditions for large-scale manufacturing, particularly with a supply chain that relies heavily on regions sensitive to extreme weather and natural disasters.

At the same time, "advancements in semiconductors will be essential to enable a new wave of transformative technologies, including quantum computing, artificial intelligence (AI), 5G, autonomous electric vehicles or Internet of Things (IoT) solutions deployed at scale with a myriad of smart connected devices,"²⁵ and critical to achieving Net-Zero Emissions goals and advancing clean energy technologies. As noted in KPMG's 16th annual global semiconductor industry outlook, wireless/5G, IoT, and automotive will be the most important drivers of industry revenue within the next two years. Digitalization within the semiconductor and other related industries will continue to accelerate, with the market for AI-related semiconductors growing to USD \$30 billion by 2022²⁶.

In addition to addressing the current chip shortage, building a self-sufficient and robust semiconductor supply chain is critical to the future-proofing of Canada's auto and medical equipment sectors, which are currently dependent on foreign-led supply chains that prioritize larger markets than Canada's. There is also a need to respond to the longer term trend that edge computing will continue to grow significantly regardless of "short-term" chip shortages.

We therefore recommend leveraging Canada's position of relative stability and existing attractive features to develop a sound business model for domestic fabrication, balanced between chip generations that meet the forecasted requirements of Canadian companies, emerging technologies with long term growth potential, and manufacturing gaps in other jurisdictions. Policies including investment and tax incentives, R&D supports, and ecosystem collaborations will both attract global foundries and promote the development of domestic ones. In particular, continuing to nurture talent in the MEMS foundry space will be important to making Canada a serious consideration for new fabrication sites. Amongst domestic companies, Teledyne DALSA is an industry leader which specializes in MEMS and sensor technologies, a

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https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

²⁵ Ibid.

²⁶ <https://advisory.kpmg.us/articles/2021/global-semiconductor-industry-outlook-2021.html>



differentiating area for Canada in semiconductor design. Increasing domestic capacity through the creation of a cluster for sensor- and MEMS-based fabrication would be advantageous to Canadian companies in this space, who would be able to take advantage of the research expertise to establish on-shore, large-scale manufacturing capabilities that both domestic and global players can use, thus achieving economies of scale. For instance, STMicroelectronics recently established the world's first "lab-in-fab" (having design co-located with manufacturing) in partnership with a research institute in Singapore and a Japanese manufacturing-tool vendor, to advance the adoption of piezoelectric MEMS²⁷. Canada may pursue a similar project with partners to set up a state-of-the-art MEMS foundry and development lab, building on Teledyne DALSA's Bromont Science Park²⁸.

Leveraging Canada's strengths in research (specifically in academia) and downstream manufacturing (auto, clean energy, etc.), as well as advantages in talent, infrastructure, and historical entrepreneurship and ecosystem through enhanced incentives and policies will elevate Canada's position in the global semiconductor supply chain and build domestic, self-sufficient capabilities that can withstand disruptions elsewhere.

2.2 Attract multinational semiconductor companies to Canada

We recommend that the federal government develop a policy framework to leverage Canada's infrastructure, manufacturing capabilities, talent and other attractive attributes to attract multinational semiconductor manufacturers and design to Canada, with the goal of announcing a new foundry investment by 2022.

In addition, we recommend investing in industrial sectors where domestic Canadian companies have comparative advantage, and where opportunities to attract non-Canadian multinationals to establish Canadian operations within a strategic policy framework that retains and attracts talent to Canada, grows Canadian jobs, and increases the number of semiconductors being produced in Canada.

Canada must signal to trade partners that the semiconductor sector is a priority for our nation, many of whom are significant players in the global semiconductor industry, in order to be positioned as a viable contender for global investment. Broader trade implications with nations should be considered as it relates to emerging technologies, including artificial intelligence, quantum science, and critical minerals.

²⁷ <https://newsroom.st.com/media-center/press-item.html/t4293.html>

²⁸ <https://parcscientifiquebromont.com/en/the-science-park/>



Strategic, mutually beneficial trade relationships will be critical to attract foreign direct investment in both the short and long-term into Canada for semiconductor (and related) design and manufacturing from both global semiconductor companies and sector-specific companies in industries such as automotive, agriculture, health, energy and consumer electronics.

There is urgency for Canada's federal government to leverage our [trade agreements](#) starting with the U.S., Taiwan, and the EU with a compelling incentive package to attract global semiconductor design and manufacturing companies to invest and build infrastructure in Canada in areas where the Council has identified as strategic, comparative advantage for Canada. The India and Taiwan governments are already in late stage negotiations to build a \$7.5 billion chip manufacturing plan onshore in India²⁹ to meet domestic and global demand for products ranging from 5G devices to electric vehicles. At the same time, there are growing concerns as the U.S. government has requested Intel, TSMC, and Samsung — which operate major chip manufacturing plants on U.S. soil — to disclose confidential client data, illustrating growing geo-political tensions in an industry which relies on a highly integrated and globalized supply chain.

Through Canada's CPTPP trade pact³⁰ with 11 Asian nations including Japan, Singapore, Malaysia, Australia, there are strategic opportunities to work with several nations: Japan, given the country's advanced research in key semiconductor technologies and strong domestic demand through auto and consumer electronics manufacturers; Malaysia, which accounts for a significant percentage of the world's semiconductor assembly, packaging, and test and is a lynchpin for packaging for chips supplied to the auto sector³¹; and Singapore, which is a major logistics hub for global trade and home to significant semiconductor manufacturing and research in advanced technologies such as millimetre-wave (mmWave) central to 6G communications³².

Additionally, the U.S., Australia and the U.K. announced a new three-way security pact (AUKUS) that Canada was not a part of and could signal a shift that might have implications for the global semiconductor supply chain as Australia, like Canada, is a major source of rare earth materials key for Lithium batteries (as noted in the U.S. 100-day supply chain review³³), and the U.K. is home to ARM, one of the world's largest semiconductor IP suppliers and whose proposed acquisition by U.S.-based Nvidia is currently under regulatory investigation by the U.K., U.S. and EU regulators³⁴.

²⁹ <https://www.econotimes.com/India-accelerates-talks-with-Taiwan-on-chip-plant-and-trade-deal-1618073>

³⁰ <https://www.international.gc.ca/trade-commerce/trade-agreements-accords-commerciaux/agr-acc/cptpp-ptpgp/index.aspx>

³¹ <https://www.reuters.com/technology/taiwan-says-resolving-chip-shortages-needs-malaysias-help-2021-10-01/>

³² <https://www.businesstimes.com.sg/government-economy/singapore-eyeing-rd-in-mmwave-to-create-niche-in-the-area-of-6g>

³³ <https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf>

³⁴ <https://www.silicon.co.uk/5g/nvidia-offers-eu-concessions-over-54bn-arm-deal-420056>



Given the interconnectedness of semiconductors and other durable products, driving parallel growth across the manufacturing sectors will support Canada's goals of building an innovative and sustainable economy, while maximizing the potential of the semiconductor industry to [create employment](#).

Analysis of current global and Canadian incentive programs, and key trade relationships, can be found in the appendices of this report.

LONG TERM (2021-2050)

2.3 Leverage Canada's talent in research and development to disrupt and innovate the current semiconductor fabrication process

The prohibitive and daunting semiconductor fabrication cycle, not to mention its high cost, is ripe for disruption and innovation. Allocating resources to researching and developing alternative approaches to manufacturing semiconductors represents a prospective paradigm shift in an industry that's central to the global economy. As a first step, we recommend optimizing National Research Council Canada assets and programs to partner closely with ecosystem leaders and industry to strategically advance at scale commercialization of research in design, algorithm, materials and process manufacturing in this sector, translating research into real application and products that have high domestic and global demand.

As the Semiconductor Industry Association reports, the current semiconductor fabrication process is intricate, requiring specialized inputs (as many as 300) and equipment "to achieve the needed precision at miniature scale":

Depending on the specific product, there are 400 to 1,400 steps in the overall manufacturing process of semiconductor wafers. The average time to fabricate finished semiconductor wafers, known as the cycle time, is about 12 weeks, but it can take up to 14-20 weeks to complete for advanced processes. It utilizes hundreds of different inputs, including raw wafers, commodity chemicals, specialty chemicals as well as many different types of processing and testing equipment and tools, across a number of stages. These steps are often repeated many hundreds of times, depending on the complexity of the desired set of electronic circuits.³⁵

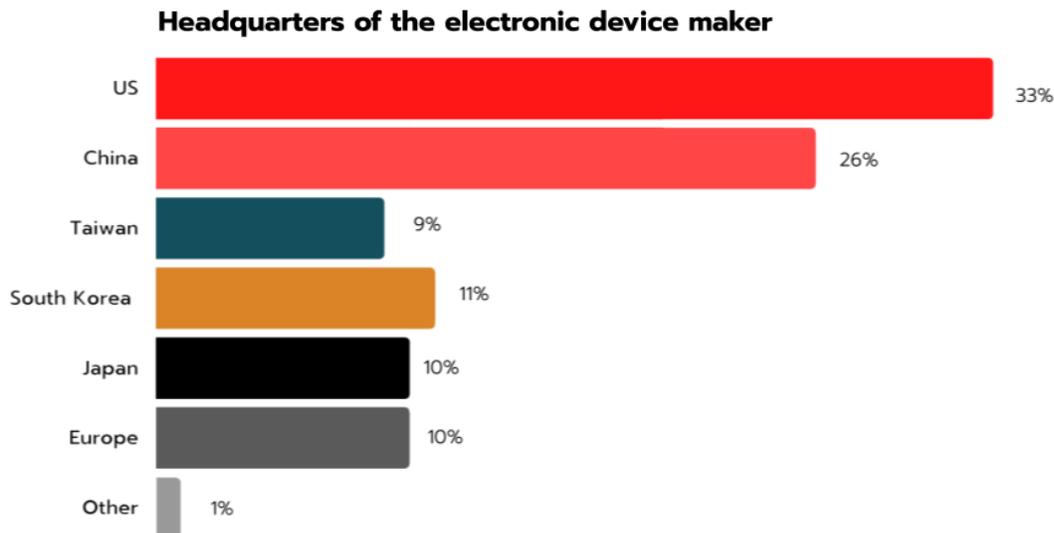
³⁵

https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

“In Scotland, we attempted to set up a semiconductor forum. The country had an existing base of large Multi-National Wafer Fabs (NEC, Motorola, DEC,) and corresponding support infrastructure, colloquially known as Silicon Glen. However, membership of the forum was strictly voluntary and it over time, failed because despite voluntary effort and energy, there was little cohesion, and a serious lack of funding.”
- John Docherty, Past SVP, Foundry Operations, Global Foundries

Given Canada's position of strength in semiconductor research and design, we recommend investing in programs and facilities that encourage talented Canadian engineers to pursue innovations designed to decrease the amount of time and resources required to build or adapt a chip fabrication facility in order to produce semiconductors at scale. Establishing Canada as a pioneering nation in the development of this “flexible fab” model would not only provide an additional source of domestic chips, but would also place Canadian talent on the global industry map, serve as a beacon to encourage further homegrown innovation in the sector, and provide opportunities for Canadian innovation to be incorporated by global partners in the next generation of semiconductor fabrication facilities and processes.

Global Semiconductor Sales by Geographic Area, 2019 (%)



SOURCE: Boston Consulting Group & Semiconductor Industry Association.
https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

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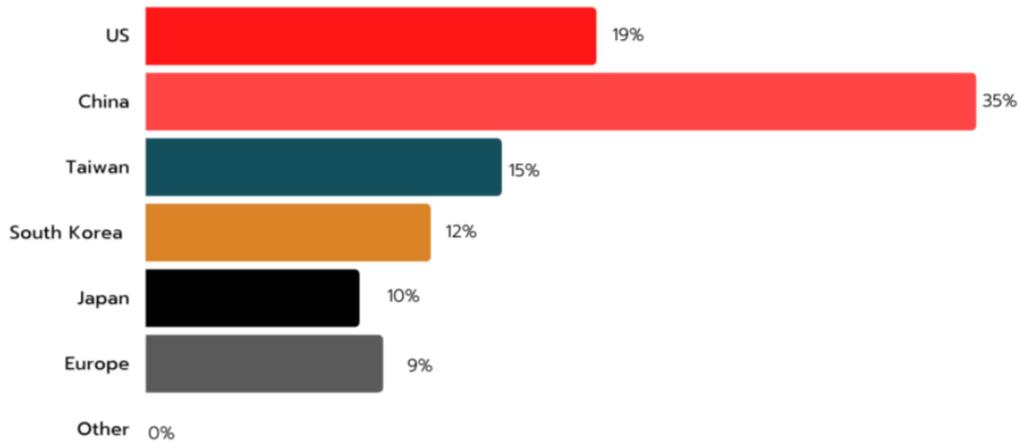
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https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf



Global Semiconductor Sales by Geographic Area, 2019 (%)

Where the device is manufactured/assembled

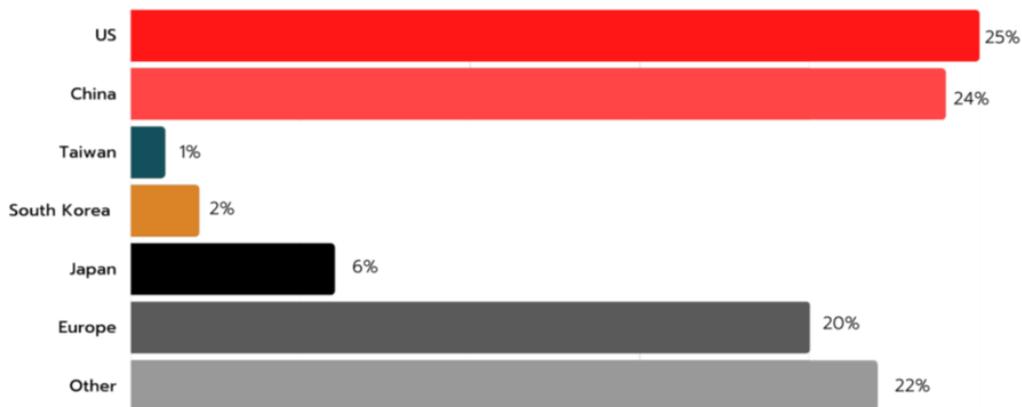


SOURCE: Boston Consulting Group & Semiconductor Industry Association.
https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

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Global Semiconductor Sales by Geographic Area, 2019 (%)

Location of the end user that purchases the device



SOURCE: Boston Consulting Group & Semiconductor Industry Association.
https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

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https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

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https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf



3. Establish a Unique Specialization and Brand for Canada

There is tremendous demand for — and value in — expertise in semiconductor design and IP. According to a report by Boston Consulting Group and the Semiconductor Industry Association, design activity “accounts for 65% of the total industry R&D and 53% of the value added” — and more resources are being poured into the design stage as chips become increasingly complex.

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Specializing in design and R&D in the semiconductor sector is a tremendous opportunity for Canada to establish itself as a vital hub of innovation in the value chain. What’s more, this specialization leans in to our existing strength in producing top engineering talent, and can be regionalized to align with key industries across the country.

Further to this, we recommend unique specializations in electric vehicles and their batteries, and sensors for use in a wide range of applications. These industries are poised for significant growth, leverage regional strengths across Canada, rely on advanced semiconductor technology, and support a wide range of upstream and downstream sectors at the core of the Canadian economy.

There are key economic sectors that have regional significance as well as high adoption, development, and fabrication of semiconductors and related products. For example, the 17 port authorities of Canada's National Port System see close to \$400 billion dollars worth of goods. However, outdated port infrastructure and limited warehouse capacity have contributed to supply chain bottlenecks in transportation logistics. British Columbia’s ports — Canada’s gateway to Asia — are in transition from manual to more automated processes through the use of sensors and semiconductors to track, monitor, and predict the flow of goods, containers, and other critical logistics infrastructure.

Canada’s auto sector, highly concentrated in Ontario, provides more than 500,000 direct and indirect jobs in Canada. By 2030, 45% of the cost of a car are the electronic systems that embed semiconductor chips. To achieve net zero emissions, by 2030 75% of passenger cars globally would need to be electric vehicles (EV). Hybrid EVs have more than 3,500 semiconductors which account for over two times the cost of the electronics in a standard car today.

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https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf



In industrial applications in the oil and gas sectors — concentrated in Alberta and Newfoundland and Labrador — automation and improved worker safety is achieved through the use of sensor technologies, while precision agriculture relies on advanced chips and sensors designed into the latest machinery.

Similarly, the mining sectors concentrated in Ontario, Quebec and B.C. are the source of rare earth minerals for large capacity batteries critical to electrification of vehicles and energy storage capabilities to achieve climate change targets and reduce GHG emissions, and (like agriculture, oil, and gas) depend on advanced machinery and instrumentation with embedded electronics and chips as well as adoption of sensors to accelerate automation and increase worker safety.

“Globally, mining companies are driving demand for sensor technologies that can be integrated into industrial equipment that can relay data in a meaningful way to drive better decision-making.”
- Don Duval, CEO, NORCAT

The government plays important roles in promoting and stimulating the industry, both in R&D to advance technology and fabrication to strengthen supply chain resilience. In SIA's analysis of the US federal chip incentives, funding will create both temporary and permanent employment, manufacturing and research infrastructure, and industry expertise. Incentives can also encourage the growth of emerging companies and attract established manufacturers to set up plants in the region⁴⁰. For example, Israel has strong policies and benefits that it is in talks with Intel about a second fab construction, whose exports accounted for 14% of Israel's total high-tech exports and 2% of its GDP in 2020⁴¹. The country now has 150 fabless semiconductor companies, R&D facilities, and design centres⁴² — third in the world after the US and Taiwan⁴³.

In the US, the share of federal government R&D investment in all funding sources towards semiconductors was at 12% in 2018, trailing behind the average across all sectors at 22%. The new USD \$52 billion pledge would likely change the dynamic. In the OECD's 2021 *Main Science and Technology Indicators* report, Canada's R&D intensity (R&D expenditure as a percentage of GDP) was at approx. 1.5%, lagging behind the OECD average of approx. 2.5%. The Canadian government's R&D budget growth also trailed behind peer countries⁴⁴. Given these trends and realities, increasing Canada's public investment in semiconductor R&D and production capacity development is critical to the health of many industries. To achieve

⁴⁰ <https://www.bcg.com/en-us/publications/2020/incentives-and-competitiveness-in-semiconductor-manufacturing>

⁴¹ <https://en.globes.co.il/en/article-israel-has-major-role-to-play-in-intel-revival-1001385860>

⁴² <https://www.reogma.com/industry-reports/semiconductor-industry-in-israel-accounted-for-16-of-high-tech-product-exports-in-2020/>

⁴³ <https://www.edn.com/fabless-goes-global/>

⁴⁴ <https://www.oecd.org/sti/msti-highlights-march-2021.pdf>



self-sufficiency of localized semiconductor supply chains, the U.S. would need an upfront investment of \$350–\$420 billion, plus an annual incremental cost of \$5–\$15 billion⁴⁵. Supply chain resiliency requires collaboration between industry and government to ensure ongoing access to required resources, including capital, talent, and technology.⁴⁶

SHORT TERM (2021-2025)

3.1 Increase incentives and support for Canadian semiconductor research and design

Canada has several major semiconductor-related ecosystem assets, with the vast majority focused on academic research and design, where Canada currently is a leader. Concentrated regions of semiconductor related research strength include:

- **Artificial intelligence** through CIFAR's AI strategy, led by Canada's three national AI Institutes: [Amii](#) (Edmonton), [Mila](#) (Montreal), and the [Vector Institute](#) (Toronto);⁴⁷
- **Nanotechnologies** in primarily Ontario, Alberta, and Quebec through the University of Waterloo [Giga-to-Nanoelectronics Centre](#), [Queen's University Nano Fabrication Kingston](#), and University of Alberta [Fabrication & Characterization Centre](#) (nanoFAB);
- **Photonics** in Ontario and Quebec through the NRC [Advanced Electronics and Photonics Research Centre](#) and [Institut national d'optique](#) (INO);
- **Sensor technologies** in Quebec and Alberta through the NSERC [Computing Hardware for Emerging Intelligent Sensing Applications](#) (COHESA) Network and [Industrial Sensor Technologies \(InnoTech\)](#);
- **Quantum science** in British Columbia, Alberta, and Ontario through [Quantum BC](#), the University of Waterloo [Institute for Quantum Computing](#) and University of Calgary [Institute for Quantum Science and Technology](#)

“The federal government had a program called Technology Partnerships Canada in the early 2000s. It was at a crucial time when we needed the money but it didn't dilute us when we raised, then we paid the government back over a period of 10 years. The win-win: we were able to grow to over \$100M USD in annual sales while generating 500 high tech jobs in Canada.”

- Brad Siim, Co-founder and COO, Sandvine

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https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

⁴⁶ Ibid.

⁴⁷ <https://www.amii.ca/latest-from-amii/dlrl-summer-school-2021/>



We recommend allocating resources to expand research programs and facilities in these areas, specifically in relation to semiconductors, by establishing NRC research chairs and NSERC-funded projects. In addition, few organizations currently focus on taking research and early-stage designs into commercialization. Existing ones include:

- **Advanced Technology Development Group (ACAMP)** in Alberta, an industry-led advanced technology product development centre for entrepreneurs with a focus on electronics hardware, firmware, software (machine learning and AI), sensors, and embedded systems;⁴⁸
- **Centre de Collaboration MiQro Innovation (C2MI)** in Quebec, a collaboration between academic and industrial sectors to accelerate commercialization of value-added products;
- **Hardware Catalyst Initiative (HCI)** in Ontario, Canada's first and only lab and incubator for founders building hardware and semiconductor-focused products led by ventureLAB Innovation Centre (ventureLAB);
- **Institut national d'optique (INO)** in Quebec, "the largest centre of expertise in optics and photonics in Canada."⁴⁹

Increasing investments in commercialization-stage assets that help companies and research institutions apply designs and innovations to tangible products will bridge the gap between R&D and fabrication. Continuing to foster the synergy between semiconductors and other scientific and technological advancements like artificial intelligence and quantum computing will also elevate Canada's role in R&D and design globally.

3.2 Invest in electric vehicle R&D and leverage Canada's strengths to develop a domestic supply chain

"The future of Canada's automotive sector is dependent on our ability to create a robust, domestic supply chain. As electrification, connectivity and autonomy of transportation becomes increasingly prevalent, we must ensure we have the ability to design, build and manufacture here in Canada to create good jobs in this sector and provide pathways for export."

- Flavio Volpe, President, Automotive Parts Manufacturers' Association

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<https://www.biospace.com/article/releases/acamp-working-with-university-of-alberta-has-developed-a-washable-cloth-based-filter-and-plastic-respirator-with-over-95-percent-filtration-efficiency/>

⁴⁹ <https://www.ino.ca/en/>



Made-in-Canada semiconductors and electronics are critical to a green recovery and Canada's leadership in the global electric vehicle and battery manufacturing supply chain. A domestic semiconductor strategy maximizes return on strategic investments, such as General Motors' self-driving technology developments in Markham and Oshawa that were instrumental to GM's Brightdrop EV600, the first EV commercial vehicle to be built at scale in Canada⁵⁰.

Canada is a strong leader in extracting and processing critical minerals and materials required in emerging areas like electric vehicle and battery production, which are industries of special importance to the world's green transformation. Moreover, there are opportunities for Canada to become a leader in EV battery recycling, a process that is increasingly needed given the limited supply of minerals like lithium and the necessity to reduce carbon footprints of countries to achieve decarbonization goals. Canada already has a strength in materials-related research, with 60 Canada Research Chairs in Materials Science and Technology or Chemical Engineering⁵¹, and CAD \$67.4 million awarded to related research projects through the NSERC in 2020-2021 alone⁵².

In the commercial space, Canadian firms like Li-Cycle, North America's largest capacity lithium-ion battery recycling company, are gaining momentum. Li-Cycle was founded in Mississauga with its manufacturing base in Kingston, Ontario, and later opened a USD \$175-million facility (its first commercial lithium-ion battery recycling Hub) in Rochester, New York, for commercial scale⁵³. Creating incentives and investments that keep the operations of domestic companies within Canada while supporting their entry into global markets will build Canada's capacity in EV battery R&D and production. Canadian companies looking to scale will continue developing their bases in Canada and foreign players will look to Canada as a promising destination for expansion, especially given Canada's existing commitments and ecosystems around electric vehicles.

Furthermore, in order to leverage and strengthen Canada's place in the global supply chain, we recommend the following:

- Pursue trade agreements specifically with the US (CUSMA), EU (CETA), Taiwan, Japan (CPTPP), Singapore (CPTPP) and Korea (CKFTA) to establish long-term commitments for Canadian-based manufacturing in industries such as EV, lithium batteries or semiconductor that require rare earth or other major minerals as direct inputs;
- Complete more in-depth research to onshore Canadian-owned semiconductor equipment manufacturing that depends on direct input of high purity chemicals where Canada may have a comparative advantage in or an abundant supply of (e.g. materials

⁵⁰ https://www.gm.ca/en/home.detail.html/content/Pages/news/ca/en/2021/Jan/0118_brightdrop.html

⁵¹ <https://www.chairs-chaires.gc.ca/chairholders-titulaires/index-eng.aspx>

⁵² https://www.nserc-crsng.gc.ca/ase-oro/Results-Resultats_eng.asp

⁵³ <https://li-cycle.com/news/li-cycle-selects-rochester-ny-as-site-for-lithium-ion-battery-recycling-hub/>



related to lithography, cleaning, etching or other key semiconductor manufacturing steps).

Given Canada's commitment to *A Healthy Environment and a Healthy Economy* through the strengthened climate plan⁵⁴, and other programs that promote the production and use of EVs such as the 5-year CAD \$280-million Zero Emission Vehicle Infrastructure Program⁵⁵, investing in EV battery R&D and manufacturing is of strategic importance to the Canadian economy and industries. Robust and resilient domestic supply chains can be developed through leveraging Canada's research expertise, entrepreneurial talent, and trade partnerships.

3.3 Invest in sensor R&D, design and manufacturing

Supporting micro-electromechanical systems (MEMS) and sensor innovation leans further into Canada's strength in design and research in the semiconductor space, in addition to the technologies requiring the chips themselves. These sectors have a strong talent pipeline, supported by valuable IP. We recommend expanding nascent investments in this space, including those by the National Research Council Canada, in order to establish a global presence for Canada.

Furthermore, in the case of sensors, there are regional opportunities to spur additional innovation in significant sectors. Accelerating adoption of sensor technologies into supply chain logistics applications supports rapidly increasing automation in the Transportation Logistics industry in British Columbia; additionally, the Oil and Gas Drilling industry in Alberta will require increasingly sophisticated sensor technologies, which Canadian semiconductor designers are poised to support. Sensor technologies have many other widespread applications, ranging from agriculture and automotive to IOT and medical devices (like ventilators). Spurring the growth of made-in-Canada supply is vital to meeting growing domestic demand, both from the private sector and government. We recommend initiating programs in a similar vein to the NRC's Artificial Intelligence for Logistics Supercluster Support Program⁵⁶ to spur growth in sensor specialization.

In addition, a focus on sensors represents an opportunity to attract additional multinational foundries that specialize in MEMS, so that a manufacturing cluster can be formed alongside Canadian MEMS companies to further build out the sector, talent, IP, and jobs in Canada.

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<https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/healthy-environment-healthy-economy.html>

⁵⁵ <https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876>

⁵⁶

<https://nrc.canada.ca/en/research-development/research-collaboration/programs/artificial-intelligence-logistics-supercluster-support-program>



This effort unites innovation happening across Canada. Southern Ontario is home to design engineering and production scale assembly and test facilities, as well as wide-ranging technical expertise and experience. Quebec houses MEMS expertise in the form of facilities such as Centre de Collaboration MiQro Innovation (C2MI), and one of Teledyne's two production-scale manufacturing foundries. Alberta hosts the other Teledyne facility, and is home to MEMS specialists as well as oil and gas talent whose experience would translate well to advanced semiconductor manufacturing.

More information about specializations in Canada's semiconductor sector can be found in the appendices of this report.

MEDIUM TERM (2021-2035)

3.4 Invest in higher education grants to empower our best and brightest to pursue R&D in essential chip technologies and to remain in Canada

The current nest of semiconductor aligned funding programs in higher education (for students, faculty, and industry) needs to be streamlined, and access made quicker and easier.

In addition, existing electronics related research funding in higher education should be augmented by additional grants that support semiconductor R&D specifically, and drive the commercialization of made-in-Canada innovations in the sector. This would further the goal of establishing Canada as a research hub, while also providing a scaffold for emerging engineers to gain the experience they need to succeed in the industry domestically.

"We find ourselves in a world where we have many talented people who don't have an opportunity to gain that experience in Canada."

- Andrew Fursman, CEO and Co-Founder, 1Qbit



Strategic, government-led grant partnerships that connect institutions and the private sector are essential to ensuring that top talent have the resources they need to conduct R&D in Canada.

For a breakdown of current postsecondary research funding opportunities, refer to the appendices of this report.

3.5 Invest in increasing testing and manufacturing capacity for sensors at scale

The focus on sensors recommended in this Action Plan represents an opportunity to attract additional multinational foundries that specialize in MEMS, so that a manufacturing cluster can be formed alongside Canadian MEMS companies to further build out the sector, talent, IP, and jobs in Canada.

As a medium-term action, we recommend that significant investments be made into sensor testing and manufacturing to both attract global sensor manufacturers to expand their footprint and investment in Canada, as well as increase Canadian-owned manufacturing at production volumes.

3.6 Develop higher education programs for sensor design

Engineering programs remain a popular choice in higher education across Canada, and our country boasts some of the highest regarded schools of engineering in the world. We recommend leveraging this position of strength to support institutions in the creation of programs focused on sensor design, including the development of chip technologies.

A specialization of this nature would support domestic growth of a key, emerging sector, while simultaneously ensuring that postsecondary students see value in their education by tracing a clear path from school to work. To that end, we recommend ensuring that Canadian companies innovating in the realm of sensor design are linked to these higher education programs through work integrated learning opportunities, thereby formalizing a reliable talent pipeline.

Semiconductor-aligned postsecondary enrollment trends are available in the appendices of this report.

LONG TERM (2021-2050)

3.7 Invest in building a global brand trumpeting Canada's specialization within the semiconductor space

Canada's bench strength as a hub of semiconductor research and design innovation casts our country against its type as a land of vast, open spaces and abundant natural resources. Competing globally in the innovation space with the U.S., and countries in Europe and Southeast Asia, will require a branding and advocacy campaign that supports the many incentives and investments called for throughout this Action Plan.

“From a manufacturing perspective, and starting from a base of near zero, investing in the semiconductor industry today is a long-term, strategic investment that requires enormous financial, human, and political capital and it is unlikely to produce net results in five years — it needs the money, the infrastructure, and the talent together, which can take a great deal of time and effort. On the other hand, investing in semiconductor design centers based on the talent available in Canada today is a simpler route, increasing the footprint of the semiconductor industry in Canada immediately.”

- Kirk Ouellette, VP, STMicroelectronics

We recommend the entrenchment of a long term global brand designed to entrench the following key messages:

- Canada is committed to supporting R&D, design, and large scale production of sensors and electric vehicle batteries, utilizing made-in-Canada semiconductor IP
- Canada's abundant resources and position of global stability makes it ideally suited as a location for large scale semiconductor fabrication
- Canada's strength in research and design is ideally suited to commercializing semiconductor IP for emerging technologies, including AI and quantum
- Canada is home to the talent and skills required to foster ongoing semiconductor innovation

4. Foster Innovation and Support Market Development

“Hardware companies and early-stage semiconductor companies have a perceived risk associated with them and they’re not valued by the capital markets, which means there is a capital market disconnect to a certain extent.”
- Whitney Rockley, Co-Founder, McRock Capital

Companies in the semiconductor sector require significant amounts of funding and patient capital, as they take years to scale and more years to see a return. Semiconductors are highly complex to design and manufacture, requiring chip companies to reinvest 22% of their annual sales to electronic device makers back into R&D, and a further 26% to capital expenditure⁵⁷.

“Even in the US up until around 2016, if you were a chip company, no VC would really talk to you and you'd have to operate on a shoestring for a long time. AI has changed all that and 5G has the potential to do the same. Both have brought in a renewed focus on what I call ‘the golden age of silicon’ back again, because it's been a while since there has been this resurgence of interest in silicon.”
- Arun Iyengar, CEO, Untether AI

Taking a chip to commercialization and volume production requires a total of USD \$20-40 million,⁵⁸ and according to a 2020 report from Boston Consulting Group and the Semiconductor Industry Association, “a state-of-the-art semiconductor fabrication facility (“fab”) of standard capacity requires approximately \$5 billion (for advanced analog fabs) to \$20 billion (for advanced logic and memory fabs) of capital expenditure, including land, building, and equipment.”⁵⁹ Global capital expenditure and R&D in the form of industry funding across the value chain totalling approximately \$3 trillion is needed in the next decade to respond to demand requirements⁶⁰. However, the ripple effect of public investment is particularly outstanding in the semiconductor industry, given its impact on downstream sectors and increasingly significant role in the tech-enabled society.

⁵⁷

<https://web-assets.bcg.com/9d/64/367c63094411b6e9e1407bec0dcc/bcgxsia-strengthening-the-global-semiconductor-value-chain-april-2021.pdf>

⁵⁸ <https://www.downingventures.com/news/the-rise-and-rise-of-the-semiconductor>

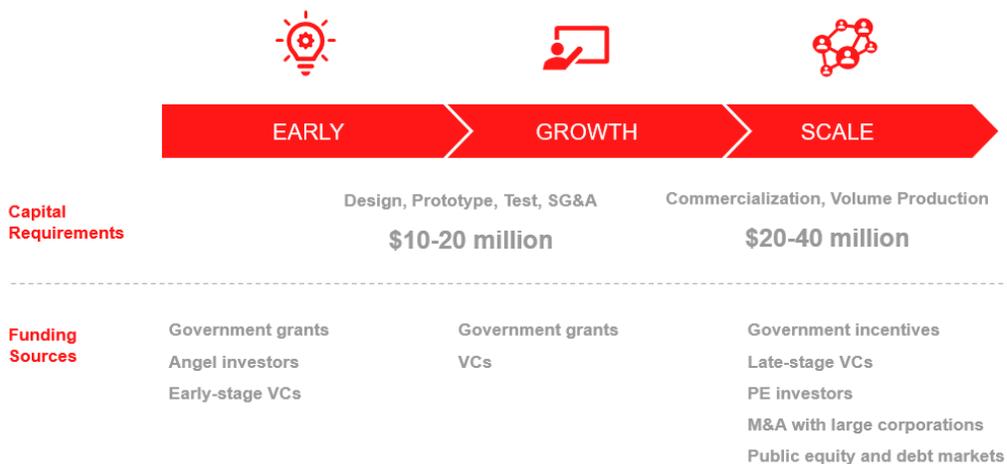
⁵⁹

<https://web-assets.bcg.com/9d/64/367c63094411b6e9e1407bec0dcc/bcgxsia-strengthening-the-global-semiconductor-value-chain-april-2021.pdf>

⁶⁰ *ibid.*

The capital requirements at all stages of a semiconductor company's growth, coupled with long commercialization timelines, create a vacuum in available funding for chip development. Canadian VCs and angel investors alone cannot provide the patient capital required to scale in this sector, particularly when software innovations present such tantalizing ROI opportunities. With this in mind, a rich array of government partnerships, supports, programs, and incentives are required to support growth in the Canadian semiconductor industry.

Capital Requirements and Funding Sources for a Semiconductor Company by Stage



Source: Downing Ventures
<https://www.downingventures.com/news/the-rise-and-rise-of-the-semiconductor>

These realities, coupled with lucrative opportunities in software development and the attraction of working in the U.S., impact Canadian postsecondary institutions, and students in their engineering programs. Deepening connections between higher education and the semiconductor industry will help prepare students to develop new innovations, and commercialize them domestically.

“Canada has some of the world’s greatest talent and it is our most singular comparative advantage, but there is an urgent need to develop, retain and attract a highly skilled workforce by building more industry-led opportunities. The semiconductor sector is a foundational one for Canada. By creating post-secondary programs that embed hands-on, practical experience and are aligned to industry, we strengthen our talent pipelines, and ensure we can support a thriving Canadian semiconductor sector.”
- David Agnew, President, Seneca College



SHORT TERM (2021-2025)

4.1 Increase investment in domestic companies that are designing and developing AI- and quantum-enabled chips

Supporting Canadian IP development in Quantum-enabled chip design is essential in order to position Canada at the forefront of a sector poised for exponential growth. This recommendation represents a “long term bet” on semiconductor development, backed by Canada’s bench strength in research and design.

Canada has a favourable research, design, and technology development advantage when it comes to AI-enabled semiconductors. Our longstanding expertise in chip design innovation, fostered by a historically strong engineering talent base, provides a strong foundation for Canada to compete globally in the development of the next generation of AI-powered technologies. Bolstering investments that advance AI chip innovation and commercialization in Canada, through direct support to companies and ecosystem partners, leans into this position of strength and positions Canada as an innovation hub in this rapidly expanding sector. In Ontario, for example, Vector Institute reports that more than 7,200 were created in the year ending March 31, 2021, matched by similar growth in talent supply and AI’s role in business objectives.

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In order for Canada to be an AI leader, and to commercialize our globally recognized research, we must have IP-rich Canadian anchor companies designing AI chips and AI-enabled chips, and selling them domestically. Our strength in AI research and design, represented by companies like Tenstorrent, Untether AI, Alphawave, must be supported by pathways to domestic procurement, including by the government itself. Presently, many of our companies sell to customers outside of Canada, but this market is in an uptick of commercialization: AI technology is being actively built into real products from anchor Canadian and global customers.

The commercialization timeline horizon for quantum is longer than that of AI; in this case, the opportunity is to ensure that there are domestic companies (like D-Wave and Xanadu) and government procurement agreements in place well ahead of when quantum is commercially viable. As with AI, we recommend supporting commercialization and seeding a domestic market for quantum-enabled semiconductors, in anticipation of this burgeoning market. Enacting broad-based support for development in this arena will mitigate the need for quantum chip

⁶¹ <https://vectorinstitute.ai/2021/10/20/ontario-ai-snapshot-the-state-of-the-provinces-ai-ecosystem-in-2020-21/>



innovators to leave Canada or be acquired by foreign-owned companies in order to commercialize their IP.

Current Canadian Semiconductor Incentives & Policy

Canada has strong foreign trade and investment relationships with many countries and MNEs. It has been ranked among the top 3 countries for doing business in the last 5 years in the G20, the easiest place to start a business in the G20, and first for its attractiveness to entrepreneurs in the OECD countries. It also had the second-largest foreign direct investment (FDI) stock to GDP ratio among the G20 countries from 2015 to 2020⁶².

Below are incentives that attract foreign MNE investment:

Stage Focus	Name	Estimated Commitment	Description
R&D	Scientific Research and Experimental Development (SR&ED) Tax Incentive Program	\$3 billion in 2016	Any company in Canada (domestic or foreign) can apply for the SR&ED program tax incentives, which allows businesses to use certain expenditures to deduct their tax liabilities. The tax credit varies from 15% to 32% depending on the province/territory that a business operates in.
Manufacturing Assembly & Test	Accelerated Investment Incentive	N/A	The incentive provides “an enhanced first-year allowance for certain eligible property that is subject to the Capital Cost Allowance (CCA) rules” ⁶³ to attract FDI into capital-intensive sectors.

Incentives for domestic semiconductor companies

Simultaneously, the Canadian government offers benefits to domestic semiconductor companies looking to innovate and grow, including R&D grants, tax reductions, and hiring incentives. However, most of these programs are catered towards the R&D stage in the supply chain and little exists in the manufacturing or assembly and test stage, reflecting the challenges Canadian companies face with commercialization and volume production.

⁶²

https://www.international.gc.ca/trade-commerce/economist-economiste/analysis-analyse/key_facts-2020-12-faits_saillants.aspx?lang=eng

⁶³

<https://www.canada.ca/en/revenue-agency/services/tax/businesses/topics/sole-proprietorships-partnerships/report-business-income-expenses/claiming-capital-cost-allowance/accelerated-investment-incentive.html>



Stage Focus	Name	Estimated Commitment	Description
R&D	Scientific Research and Experimental Development (SR&ED) Tax Incentive Program	\$3 billion in 2016	Any company in Canada (domestic or foreign) can apply for the SR&ED program tax incentives, which allows businesses to use certain expenditures to deduct their tax liabilities. The tax credit varies from 15% to 32% depending on the province/territory that a business operates in.
R&D	Strategic Innovation Fund (SIF)	\$52.1 billion to date	Funding is granted to large innovation projects valued over \$10 million by for-profit companies (industry R&D, scale and growth, retention) or nonprofit networks or organizations that support the innovation ecosystem ⁶⁴ .
R&D Manufacturing (Talent)	Innovation and Skills Plan	~\$3-4 billion per year since 2017	The Canada Innovation and Skills Plan launched in 2017 is expected to create STEM education opportunities, 140,000 jobs, and \$50 billion in Canada's economy over 10 years. The plan aims to build "innovation ecosystems through new partnerships, bridging the gap from idea, to commercialization, to growing globally minded firms." ⁶⁵ Public investments into the plan have already attracted private investments that drive the innovation sector forward, especially in VC funding.

⁶⁴

https://www.international.gc.ca/trade-commerce/economist-economiste/analysis-analyse/key_facts-2020-12-faits_saillants.aspx?lang=eng

⁶⁵ https://www.ic.gc.ca/eic/site/062.nsf/eng/h_00105.html

4.2 Protect domestic Intellectual Property, and support its growth and commercialization

“What is most important to me is that we have those Canadian companies staying here, growing and scaling here, and commercializing globally. The outcome is Canadian companies owning critical IP in major markets.”

- Jim Hinton, Co-Founder, Innovation Asset Collective

The semiconductor industry is IP intensive; one patent in the semiconductor industry has the potential to translate into billions of devices, generate revenue and drive economic growth. Given the international trend toward onshoring semiconductor supply chains, protecting Canadian IP in this sector has significant national security implications. Many semiconductor innovations develop inside our academic institutions — these require additional support in order to commercialize domestically, before IP developed in Canada is swallowed up by offshore entities.

Globally, top patent holders are semiconductor companies or companies that embed semiconductor technology into their products (e.g. Apple, Google, Samsung)⁶⁶. Canadian SMEs, for expediency or financial reasons, have often elected to sell or divest their IP to foreign entities, thus foregoing Canada's opportunity to fully realize the revenue, employment, and return on investment [into Canadian jobs](#), GDP, and economic growth. Moreover, a study by the Institute for Research on Public Policy (IRPP) confirmed that the share of Canadian-made patents sold to foreign entities/countries over the past twenty years has increased substantially, from 18% to 45%⁶⁷.

IP is a critical pillar that Canadian companies require to have a truly sustainable competitive advantage. Patents in particular are more common in semiconductor and hardware-based technologies and products. Moreover, IP-rich companies can create significantly more enterprise-value over the long run, requiring deeper, more specialized engineering expertise. This leads to a more robust pipeline of highly skilled jobs that retains Canadians and attracts global talent to Canada. IP is also a critical element to raising growth capital, as investors often place increased valuations on companies with strong intellectual property or patents, compounded by the current investor landscape in Canada.

⁶⁶ <https://www.statista.com/statistics/274825/companies-with-the-most-assigned-patents/>

⁶⁷ <https://irpp.org/wp-content/uploads/2019/08/To-Sell-Or-Scale-Up-Canadas-Patent-Strategy-in-a-Knowledge-Economy.pdf>

“The real gold in our industry is IP. We need to adjust our support programs to value IP assets.”

- Niraj Mathur, Founder and CEO, BluMind.AI

In order to protect domestic IP, other jurisdictions have successfully implemented patent box concepts. For example, the UK offers a reduced rate of 10% Corporate Tax if it exploits patented inventions and innovations, and Israel provides “a reduced corporate income tax rate of 6% on IP-based income and on capital gains from future sale of IP”⁶⁸ through its Innovation Box regime. Canada can follow similar models to:

- Explore the creation of a patent box as an incentive for IP to stay in Canada by reducing profits derived from IP.
- Implement subsidies for Canadian investors seeking/obtaining patent protection in Canada.
- Experiment with more stringent national security “tests” like those in the *Investment Act* applied to mining and other natural resource assets to intangible assets like those in the semiconductor sector, especially as it relates to sale of such assets to foreign ownership.

Canadian semiconductor companies are developing and producing innovative new ideas, and their inventions are in demand on a global scale. We support widespread calls for a robust strategy, led by incentives and support programs to seed the development and commercialization of Canadian IP; we believe it is vital to ensuring that Canada remains competitive in the knowledge economy.

The marketplace frameworks necessary to govern the growth of Canada’s semiconductor industry require guidance from a steady hand, underpinned by data and informed by a global view to the shifting economic realities of an economy based on innovation and ideas. We echo calls from technology leaders for increased federal capacity to create research-backed policies to inform Canada’s knowledge economy strategy.

Specific policies should protect Canadian supported IP and limitations on foreign ownership of Canadian companies in strategic industries, in exchange for supply of critical and rare minerals and chemicals required for semiconductor-related industries like electric vehicles or lithium batteries, or semiconductor manufacturing processes.

“The important piece is Canadian-owned IP. I would be spending it in major markets or where my major competitors were — that’s where I would be building my IP position.”

- Mike McLean, CEO, Innovation Asset Collective

⁶⁸ <https://www.fdiintelligence.com/article/69813>



In 2020, the Government of Canada announced an Intellectual Property Strategy, “an investment of \$85.3 million over five years to help Canadian businesses, creators, entrepreneurs and innovators understand, protect and access intellectual property (IP) through a comprehensive IP Strategy,” indicating a strong commitment to Canadian IP⁶⁹. This investment would be further strengthened by allocating a dedicated stream of funding to IP-intensive technologies like semiconductors; protecting domestic innovation in this sector has critical economic and national security implications. As the Council of Canadian Innovators’ October 2020 open letter to the federal government points out, “The digital transformation over the past 30 years has created a new kind of economy, where wealth and power are derived from control of data and ownership of valuable intellectual property... IP and data are now the world’s most valuable business and national security assets.”⁷⁰

Additional information about the current state of Canadian electronics IP is available in the appendices of this report.

4.3 Enhance investment opportunities to fill a major gap in access to patient capital

“One of the biggest concerns we have is the capital requirements to get these businesses off the ground, to a state where they hit that commercialization stage and then the scale stage.”

- Whitney Rockley, Co-Founder, McRock Capital

In Canada, semiconductor and hardware companies currently face a gap in access to domestic sources of capital, especially in pre-seed, seed, and early-stage rounds as well as later stage, leading to higher percentages of foreign ownership in Canadian companies. Semiconductor companies can take up to 5 to 7+ years to commercialize a chip to volume production, potentially longer in end products such as electric vehicles and EV batteries. Therefore, sources of “patient” Canadian capital are required, as well as the technical and sector experience to complete the due diligence for semiconductor or deep-tech-related investments like those available through ventureLAB’s Hardware Catalyst and national Capital Investment Program.

⁶⁹ <https://www.ic.gc.ca/eic/site/108.nsf/eng/home#accordion-item-3>

⁷⁰ <https://canadianinnovators.medium.com/its-time-for-nation-building-fb0e6fb4fa19>



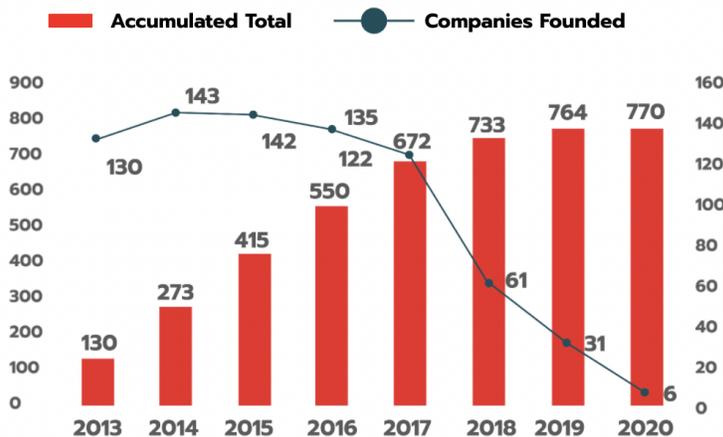
“The tech can be very difficult to understand, so lack of expertise is a gap. The other thing that scares me is the amount of capital that might go into a semiconductor company. So one of the problems with seed stage investing is sometimes we get washed out. It takes a lot more capital and a lot more rounds of capital. So biotechs for example, might not show revenue for 15 years, and the seed stage investors don’t do very well in those companies.”

- Colin Webster, Co-Founder, RISC Capital

Due to the high cost to develop a chip, which can be upwards of over \$100 million, there are few Canadian venture capital funds that are able to make the initial and follow-on investments required to scale a semiconductor or related hardware company. One such opportunity is the Deep Tech Venture Fund⁷¹ of the Business Development Bank of Canada (BDC). We recommend establishing a program whereby venture capitalists seeking to invest in semiconductor innovation could apply to be a Deep Tech Trusted Partner in order to expedite the process of unlocking BDC funding.

“On the investment side, there's a fixation on ARR and MRR, and then a quick return to build a product quickly. That's a blocker to hardware.”

- Brad Siim, Co-founder and COO, Sandvine



SOURCE: Statistics Canada

New Canadian semiconductor companies require foreign (often U.S.) sources of venture capital early on to continue product development, increasing the likelihood for those companies to relocate or exit to the U.S. rather than continue to scale in Canada. For instance, Alphawave IP, a Canadian-founded company, set up research and development headquarters in Cambridge,

⁷¹ <https://www.bdc.ca/en/bdc-capital/venture-capital/funds/deep-tech-venture-fund>



U.K., along with pursuing its IPO through the London Stock Exchange to gain greater access to capital⁷². Most funds in Canada may make one or two deals as part of a larger fund, usually with a U.S. VC firm as the lead, but very few have the deep technical expertise or fund size to support multiple semiconductor deals.

Since 2013, the rate of semiconductor and hardware-related companies being founded in Canada has fallen significantly, in part due to the lack of Canadian-sources of early-stage capital (pre-seed, seed, and Series A) and late-stage capital to support growth. As a result, there is a need for new companies in this sector to tap into venture capital sources much earlier than compared to 15 years ago, which comes at the risk of an early dilution of capital⁷³.

To reduce capital barriers for semiconductor companies and retain innovative SMEs within Canada, we recommend the following policy actions:

- Leverage the proven model in flow-through shares such as BC's [mining flow-through share \(B.C. MFTS\)](#), which offers a non-refundable tax credit of 20%, and apply it to deep tech sector investments and companies, especially those in semiconductor.
- Leverage Quebec's proven model of venture capital and investment funds through [Investissement Québec](#) as a framework for a national model to support SMEs at the seed, start-up, growth or buyout stages.
- Facilitate public-private funds to VCs firms with requirements to invest in semiconductor companies and hire semiconductor experts.
- Establish an early-stage risk capital fund and access to patient capital to enable Canadian semiconductor companies and IP to scale in Canada. This initiative should emulate the structure of previously established seed funds with a proven success record in the technology and innovation space, such as the [MaRS IAF](#). Critically, the fund should be steered by stakeholders with a deep understanding of the semiconductor industry, and focus on investments that advance innovation in the sector.
- Invest strategically in proven technology innovators developing in-demand semiconductor IP.

“There's good technology being developed in the universities, but in terms of how that is being protected, most universities tend to be very piecemeal in that approach. This can make it challenging for companies to engage in and get the protection they may be looking for. That's on top of having to deal with different licensing regimes at different commercialization terms from universities.”

- Mike McLean, Co-Founder / CEO, Innovation Asset Collective

⁷² <https://nmi.org.uk/alphawave-ip-puts-chips-on-table-with-london-float/>

⁷³ CrunchBase, ventureLAB estimates



As semiconductor technologies advance to meet the size and power requirements of the latest products which embed electronics and semiconductor technologies (from electric vehicles to mobile phones), and as the cost of development and manufacturing continues to increase substantially, centralized public-private investments into ecosystem infrastructure such as ventureLAB's Hardware Catalyst Initiative or C2MI to reduce the barrier of entry for Canadian companies is critical for Canada to be well positioned as a global leader in semiconductor research, design, and manufacturing.

Learn more about Canada's investment capital strengths in the appendices of this report.

4.4 Launch targeted innovation programs around chip enabled technology within higher ed institutions

Making the jump from academic research to commercialization can be tricky in any industry, but given the extended nature of the semiconductor life cycle, the long time to market of IP is a prohibitive barrier for talented entrepreneurs. We recommend providing support programs to bridge this gap.

There has been an increasing percentage of students pursuing STEM postsecondary education, and Canada has strength in academic research in electronics and semiconductor materials. However, many students are choosing to focus on academic streams that point away from careers in the semiconductor industry, and Canadian graduates from STEM programs are susceptible to the "brain drain" of talent lured by employment opportunities in other countries, particularly the U.S.

- Increase and promote postsecondary programs exclusively focused on core fundamentals required for chip design or chip manufacturing, with work integrated learning experiences at Canadian-own semiconductor or related companies for students.
- Create new programs dedicated to critical semiconductor design fields where Canada has comparative research and/or commercial application advantages either directly or in adjacent technologies e.g. AI, quantum, sensor/MEMS
- Establish a new research institute exclusively dedicated to semiconductor and related research as a public-private partnership, similar to models applied in the Perimeter Institute for Quantum Physics or the Vector Institute for Artificial Intelligence. Such institutes would work to complement the existing university- or college-specific NSERC grants for various research topics or appointed chairs.



- Establish semiconductor and related research as a priority research sector for NSERC and Tri-Council activities. There are also opportunities for challenge-based research, potentially in collaboration with favourable trade partners, like the Joint Call for Quantum Technologies between NSERC and the European Commission or the Joint Call for Hydrogen projects between Canada and Germany.
- Adopt or incorporate Quebec's CEGEP model that streams students prior to postsecondary education into specific technical disciplines.
- Create new programs to attract experienced workers to the semiconductor design and manufacturing sectors to Canada; consider re-skilling programs for traditional oil and gas or automotive workers.
- Increase exposure to the semiconductor industry in high school and postsecondary.

4.5 Incubate and support made-in-Canada entrepreneurial ventures in the semiconductor industry

Incubator programs within and beyond postsecondary institutions are growing in popularity across Canada. However, in the technology sector, they are better suited to software development than to hardware innovations like semiconductors, because they tend to be programmed in short sprints designed to bring an idea to market quickly. Semiconductor IP development requires a longer-range approach that emulates the patient capital required for semiconductor commercialization.

There are ecosystem commercialization anchors in key regions where there is an opportunity to increase investment in order to expand the reach, scope and impact of critical commercialization initiatives. ventureLAB's [Hardware Catalyst Initiative](#) is Canada's first and only initiative exclusively focused on semiconductor founders and commercializing products at scale, featuring a unique combination of a state of the art lab based in Ontario with access to capital-intensive design and test, access to deep sector expertise through the ventureLAB team and a global partner ecosystem of over 25 industry and manufacturing. [Quebec's C2MI](#) is a significant R&D and prototyping centre for microelectronics and [Alberta's ACAMP](#) features an industry-led advanced technology product development centre. We recommend the following actions to address this situation:

- Increase investment into ecosystem assets and programs that focus on commercializing at scale, eliminating capital intensive barriers through access to state-of-the art labs and a network of experienced experts in the semiconductor sector and enabling the success of Canadian founders.
- Prioritize investments into design and prototype capacity critical for commercialization.

4.6 Establish the federal government as a primary semiconductor customer for Canadian chip technology

**"In the US and in Europe, the government is an early adopter of technology, making it easier for businesses to grow and scale."
— Claude Jean, Executive Vice President and General Manager, Foundry Operation, Teledyne DALSA Semiconductor**

Increased government procurement of made-in-Canada semiconductors and chip technology represents a significant and vital injection of capital into the sector. This is an established practice in other countries, including China⁷⁴, and can be leveraged to drive commercialization of made-in-Canada IP and increase scale of domestic chip fabrication. We recommend enacting policies to ensure that chip technology is leveraged in government procurement processes whenever it is feasible to do so.

MEDIUM TERM (2021-2035)

4.7 Recruit high profile international experts to pursue research and development around next generation chips and flexible fabrication

Top talent attracts top talent. We recommend a government-supported model for semiconductor R&D funding that attracts leading international experts to Canada. The mission: To do for semiconductor innovation specifically what The Perimeter Institute has done for theoretical physics. This Waterloo institution, envisioned and initially funded by Mike Lazaridis more than two decades ago, has since engaged deeply with a wide range of world-renowned talent, including Dr. Stephen Hawking and Dr. Neil Turok.

Recruiting top international talent to Canada is a critical step in ensuring that Canadian-trained engineers working in the semiconductor sector (and the IP they develop) are compelled to remain here and continue to innovate in this space.

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<https://www.chinamoneynetwork.com/2018/05/23/china-supports-local-semiconductor-firms-by-adding-them-to-government-procurement-list>



LONG TERM (2021-2050)

4.8 Foster a diverse talent pipeline between higher education and the semiconductor industry

“Having more access to qualified people, more grads coming out of electrical engineering colleges and making immigration easier into Canada would all be helpful for us growing the business.”

- Jim Witham (CEO, GaN Systems)

“Across Canada, our engineering programs are good, and we have good fundamental research. Our graduates are in demand around the world.”

- Vincent Gaudet (Department of Computer and Electrical Engineering, University of Waterloo)

Canada is a highly regarded [producer of top engineering talent](#). Several Canadian postsecondary engineering programs rank among the best in the world⁷⁵, and international enrollment has steadily increased in the past decade⁷⁶.

“Engineering schools are doing a really good job in training students; they are extremely motivated to learn. It's just hard for Canadian companies to get them after they graduate.”

- Taj Manku (Founder and CEO, Cognitive Systems Corp.)

However, despite strong engineering enrollment numbers overall, [interest in core engineering programs](#) central to the semiconductor industry (particularly electrical engineering) is declining⁷⁷ in favour of programs geared toward fields like software development. Meanwhile, graduates of STEM programs, including engineering, are [susceptible to the “brain drain”](#) of talent lured away to by higher salaries and reputation to work for companies in the U.S. and elsewhere⁷⁸.

⁷⁵ <https://www.topuniversities.com/university-rankings/university-subject-rankings/2021/engineering-technology>

⁷⁶ <https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3710016301>

⁷⁷ <https://engineerscanada.ca/reports/canadian-engineers-for-tomorrow-2019>

⁷⁸ <https://brocku.ca/social-sciences/political-science/wp-content/uploads/sites/153/Reversing-the-Brain-Drain.pdf>



“I think we have to consider that, unless we're okay with becoming the feeder source for The States, then it isn't just about salary. Why do they go? Because the infrastructure is there — they can practice the skills that they have. So we need to develop the infrastructure in Canada.”

- Darren Lawless (Assistant Vice-President of Research, Innovation and Partnerships, McMaster University)

“We tend to lose a lot of our undergraduate talent. A common theme seems to be that we have difficulty recruiting domestic talent.”

- Vincent Gaudet (Department of Computer and Electrical Engineering, University of Waterloo)

These challenges are further compounded by an [underrepresentation of Indigenous people and women](#) in engineering — a key priority in the current Engineers Canada strategic plan⁷⁹.

Like other engineering- and technology-related fields, increasing diversity and promoting inclusion in the semiconductor industry is crucial to the advancement of talent and the industry. A joint study by Accenture and GSA found that women represent just 10–25% of the workforce in the semiconductor industry, with less than 1% in director roles and above. While companies provide benefits to existing employees like flexible scheduling and maternity leave, they invest little in more progressive programs including recruitment efforts⁸⁰.

Indigenous peoples are also underrepresented in the engineering workforce; Engineers Canada reports that Indigenous engineers represented 3% of Canada's engineering workforce in 2016 and 1.2% of undergraduate engineering enrollment in 2017, despite making up more than 4.9% of Canada's population at the time. In response to these trends, the organization has called upon the federal government to provide “funding outreach, access, bursaries, mentorships, as well as work-integrated-learning opportunities that encourage members of underrepresented groups, specifically women and Indigenous peoples, to pursue engineering education and remain in careers related to engineering.”⁸¹

⁷⁹ <https://engineerscanada.ca/sites/default/files/board/engineers-canada-strategic-plan-2019-2021.pdf>

⁸⁰

<https://www.gsaglobal.org/wp-content/uploads/2020/05/BRIEF-GSA-Women-in-the-Semiconductor-Industry-Survey-Results-2019.pdf>

⁸¹ <https://engineerscanada.ca/sites/default/files/public-policy/nps-diversity-inclusion-en.pdf>



In response, we recommend a government-led initiative to build a national talent pipeline that leverages the resources and reputation of Canadian postsecondary engineering programs and semiconductor companies to turn talented engineering students into Canadian semiconductor entrepreneurs and innovators. In particular, we recommend creating work integrated learning partnerships and establishing a nationwide focus on building [adaptable, future ready skills](#) designed to level the playing field for underrepresented groups and bridge the gap between academic study and success in the semiconductor industry.

Additional data and stakeholder insights into [semiconductor talent and skills](#) are available in the appendices of this report.



Appendix A: Research Report Data & Background Information

What are semiconductors?

Semiconductors — or “chips” — are tiny devices that power virtually every modern-day technology and product: consumer electronics like smartphones or gaming consoles; home appliances like refrigerators or smart thermostats; electronics required to run businesses such as computers, servers, point-of-sale devices, and information and interaction terminals; transformative technologies like electric and autonomous vehicles; life-saving medical devices like ventilators; technology in cybersecurity and national defence; and tech-enabled innovations in traditional sectors like mining, energy, agriculture, and many more.

Most people don't realize the massive compute power required inside one of these chips. For example, the Apple iPhone 12 requires a chip that contains 11.8 billion semiconductor transistors, capable of producing 11 trillion operations per second⁸². In comparison, Intel's 8086 processor introduced in 1976 contained 29,000 transistors⁸³. It is miniaturization and innovation like this that enables the most advanced technologies inside the smallest form factor, like smartwatches or 4K resolution cameras on our mobile phones.

As technology continues to get “smarter” and traditional sectors modernize, the demand for semiconductors continues to increase exponentially. This, combined with the increased demand for consumer electronics due to a shift in the global workforce toward working from home in 2020 due to the global pandemic, has led to a global chip shortage, impacting production and supply of chips and end-user products.

The global chip shortages will continue to exacerbate supply chain disruptions and time-to-market delays in major industrial sectors central to Canada's economic recovery from automotive, sustainable energy, and agriculture — industries already struggling to reopen in a new COVID-19 reality. Canada's auto sector has been particularly hard hit, with production shutdowns⁸⁴, vehicle shortages, and sales declines⁸⁵.

⁸² <https://www.bbc.com/news/technology-54510363>

⁸³ <https://www.computerhistory.org/revolution/story/330>

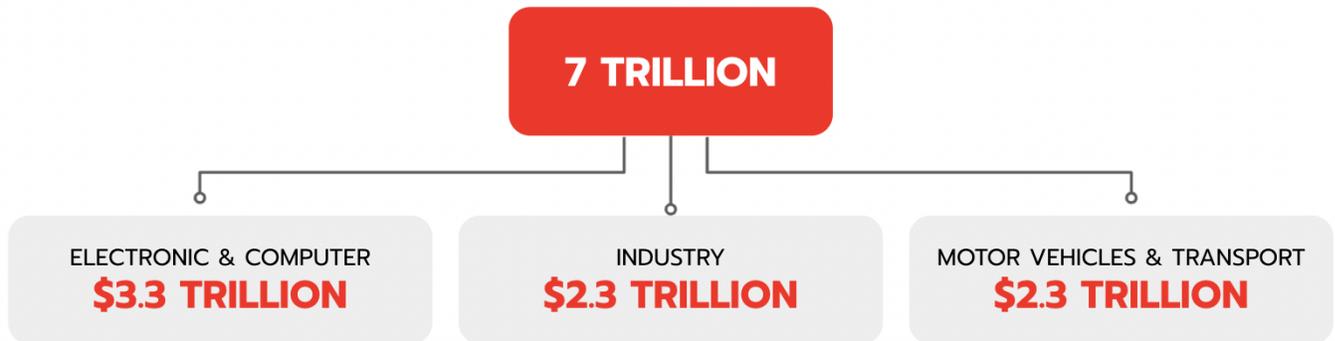
⁸⁴ <https://globalnews.ca/news/8162503/gm-cuts-north-american-production-chip-shortage>

⁸⁵

<https://www.bnnbloomberg.ca/canadian-auto-sales-fall-11-4-in-august-due-to-shortages-caused-by-chip-is-sues-1.1647294>



The Semiconductor Industry's **Total Economic Activity***



***TOTAL ECONOMIC ACTIVITY**
 The economic contribution of companies that attribute more than 5% of their output growth to the semiconductor.

SOURCE: Global Semiconductor Alliance. <http://www.semismatter.com/why/>

The Semiconductor Industry's **Contribution to GDP**



SOURCE: Global Semiconductor Alliance. <http://www.semismatter.com/why/>

⁸⁶ <http://www.semismatter.com/why/>



Recent Trends in the Global Semiconductor Industry

As the Semiconductor Industry Association recently reported, from 1990 to 2020, “the semiconductor market grew at a 7.5% compound annual growth rate, outpacing the 5% growth of global GDP during that time.”⁸⁷ The Association further notes that semiconductor “innovations have created tremendous economic growth: an estimated additional \$3 trillion in global GDP from 1995 to 2015 and an incremental \$11 trillion in indirect impact,” and that semiconductors are the world’s fourth-most-traded product after only crude oil, refined oil, and cars.”⁸⁸

According to the World Semiconductor Trade Statistics Spring 2021 forecast⁸⁹, the global semiconductor market is expected to grow to \$551 billion in 2021 and \$606 billion in 2022 with all major geographies (Americas, Japan, Asia, Europe) experiencing significant year over year growth, in part driven by the backlog in demand exacerbated by delays due to the global pandemic. The market is expected to grow 12.5% in 2021 compared to 10.8% in 2020, led by downstream demand in 5G, laptops, servers, smart home and wearables, automotive, and WiFi access points. However, the semiconductor industry is historically volatile and subject to significant cyclical swings that are driven by global financial and economic conditions.

As noted in KPMG’s 16th annual global semiconductor industry outlook⁹⁰, wireless/5G, Internet of Things (IoT), and automotive will be the most important drivers of industry revenue within the next two years. Digitalization within the semiconductor and other related industries will continue to accelerate, with the market for AI-related semiconductors growing to \$30 billion by 2022⁹¹. Meanwhile, revenues for autonomous vehicle chips are expected to rise to about \$29 billion per year by 2030, representing about \$350 per vehicle, in addition to the many other automotive components reliant on semiconductors, including infotainment systems, connectivity, engine control units, digital instrument panels, and more.

On the other hand, the top issues facing the semiconductor industry over the next three years are nationalism (cross border regulation, tariffs, trade policies, national security policies), supply chain disruption, and talent risk. At the same time, Taiwan experienced its worst drought in over 50 years this past summer, creating challenges to supply sufficient water. Each day, 150,000 tonnes of water — equivalent to 80 standard swimming pools — is required to cool the foundry to safe operating levels. Water shortage has forced TSMC to evaluate alternative sources from

⁸⁷

https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

⁸⁸ Ibid.

⁸⁹ <https://www.wsts.org/76/Recent-News-Release>

⁹⁰ <https://advisory.kpmg.us/articles/2021/global-semiconductor-industry-outlook-2021.html>

⁹¹ <https://www.pwc.com/gx/en/industries/tmt/publications/global-tmt-semiconductor-report-2019.html>

other parts of the tiny islands to ensure plants avoided any shutdowns amidst soaring demand and backlog for chips⁹².

5 key vulnerabilities identified in the semiconductor supply chain

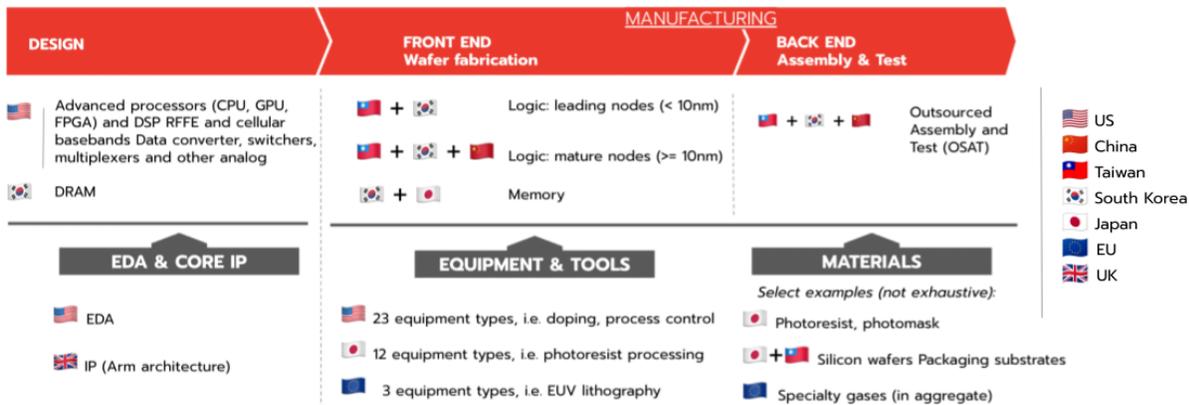
Risk Factor	Description	Current examples
High geographic concentration of some activities	Single points of failure which may be disrupted by natural disasters, infrastructure failures, cyberattacks or geopolitical frictions	<ul style="list-style-type: none"> Wafer fabrication Assembly, packaging & testing Some specialty materials
Geopolitical frictions	Broad export controls over inputs or technologies with no viable alternative suppliers in other countries	<ul style="list-style-type: none"> US-China frictions Japan – S. Korea frictions
National self-sufficiency policies	National industrial policies that seek broad import substitution or broadly discriminate against foreign suppliers, leading to distortion in global competition and risk of overcapacity	<ul style="list-style-type: none"> China policies in pursuit of "self sufficiency" across the semiconductor value chain
Talent constraints	Current growth in talent pool of Science & Engineering graduates is insufficient to meet the industry demand for technical talent	<ul style="list-style-type: none"> All countries, but US in particular given leadership in R&D intensive activities and reliance on attracting & retaining global talent
Stagnation in funding of basic research	Government programs and funding play a critical role in basic research, which is essential for the semiconductor industry	<ul style="list-style-type: none"> US government-funded R&D in semiconductors has stagnated and is below overall level across all sectors

SOURCE: Boston Consulting Group & Semiconductor Industry Association.
https://www.semiconductors.org/wp-content/uploads/2021/03/BCG_Strengthening-the-Global-Semiconductor-Supply-Chain_Antonio-Varas-and-Raj-Varadarajan.pdf

93

50+ points of high geographical concentration across the supply chain (but not all with the same level of associated risk)

VALUE CHAIN ACTIVITIES WHERE ONE SINGLE REGION ACCOUNTS FOR ~65% OR MORE OF GLOBAL SHARE¹



¹ For Design, EDA & Core IP, Equipment & Tools and Raw Materials: global share measured as % of revenues, based on company headquarter location. For Manufacturing (both Front End and Back End) measured as % of installed capacity, based on location of the facility Sources: BCG analysis with data from Gartner, SEMI, UBS, SPEEDA

SOURCE: Boston Consulting Group & Semiconductor Industry Association.
https://www.semiconductors.org/wp-content/uploads/2021/03/BCG_Strengthening-the-Global-Semiconductor-Supply-Chain_Antonio-Varas-and-Raj-Varadarajan.pdf

94

⁹² <https://asia.nikkei.com/Business/Tech/Semiconductors/TSMC-tackles-Taiwan-drought-with-plant-to-reuse-water-for-chips>

https://www.semiconductors.org/wp-content/uploads/2021/03/BCG_Strengthening-the-Global-Semiconductor-Supply-Chain_Antonio-Varas-and-Raj-Varadarajan.pdf

https://www.semiconductors.org/wp-content/uploads/2021/03/BCG_Strengthening-the-Global-Semiconductor-Supply-Chain_Antonio-Varas-and-Raj-Varadarajan.pdf



The world's semiconductor manufacturing is currently concentrated in East Asia, and can expect that typhoons sufficient to disrupt their suppliers will become two to four times more likely by 2040 due to climate change⁹⁵. On the other hand, Samsung reported losses of \$268 million after its Austin, Texas fabrication plant had to shut down due to extreme cold weather in Texas in February 2021. Any supply chain interruption could lead to long production disruptions for downstream sectors of up to a year.⁹⁶ As climate risks continue to disrupt industries, semiconductor companies will likely look to diversify their fabrication locations to ensure production resilience.

Semiconductors are found in many consumer products, including home appliances, consumer electronics, automobiles, and more. For the average consumer and many Canadians, it means the possibility of longer wait time for an appliance or simply sourcing a component for an appliance repair. In home electronics, gaming consoles, mobile phones, and tablets are experiencing unprecedented demand. In the auto sector, consumer demand skyrocketed, contrary to forecasts during COVID from auto makers. In a traditional vehicle, chips or sensors are typically required for standard features like power windows or heated seats, whereas more advanced electronics are needed in newer and electric vehicles to power features like driving assist and blind spot detection. This means that certain car models may not be available, or the wait time is longer for a customized model. Canadians have experienced skyrocketing prices for rental vehicles⁹⁷ as rental car companies sold their fleets to reduce operational costs in 2020 only to find that they cannot purchase replacement vehicles to meet soaring demand from consumers eager to travel as countries, including Canada, reopen borders and lift travel restrictions⁹⁸.

⁹⁵

<https://www.mckinsey.com/~media/mckinsey/business%20functions/sustainability/our%20insights/could%20climate%20become%20the%20weak%20link%20in%20your%20supply%20chain/could-climate-become-the-weak-link-in-your-supply-chain-v3.pdf>

⁹⁶ Ibid.

⁹⁷ <https://globalnews.ca/news/7981592/car-rental-shortage-canada-covid/>

⁹⁸ <https://www.forbes.com/advisor/travel-rewards/car-rental-prices-are-up-what-are-the-alternatives/>

Canada and our Role in The Global Semiconductor Industry

Industry Players by Value Chain Layer



**Companies are illustrative, not exhaustive*

Economic Scenarios for Canada

The Canadian economy has rebounded recently; employment numbers returned to pre-pandemic levels in September.⁹⁹ However, the semiconductor shortage has had a sizable negative impact on Canada's production and exports, particularly in the auto sector¹⁰⁰. Supply bottlenecks have not only hindered economic growth, but also contributed to price inflation, with the August CPI remaining above 3%¹⁰¹. Since September 2020, "real GDP in the motor vehicles and parts manufacturing industry has fallen by 26.8%," driven by auto plant shutdowns¹⁰². While the overall labor market recovery has been strong, employment in manufacturing has seen a decline in Ontario — one of the leading provinces in manufacturing. Risks of the Delta variant and supply chain disruptions has led leading banks to revise down their projections for Canada's GDP growth — National Bank of Canada changed their forecast for 2021 real GDP growth from 6% to 5%¹⁰³. Going forward, the strength of the manufacturing sectors, which is highly dependent on semiconductor supply, will continue to shape Canada's growth, inflation, and

⁹⁹ <https://www.cbc.ca/news/business/canada-jobs-september-1.6204511>

¹⁰⁰ <https://ici.radio-canada.ca/rci/en/news/1820602/canadas-gdp-shrank-by-0-3-in-2nd-quarter-ending-9-month-streak-of-expansion>

¹⁰¹ <https://www.bankofcanada.ca/2021/09/fad-press-release-2021-09-08/>

¹⁰² <https://economics.td.com/ca-man-forward>

¹⁰³ <https://www.nbc.ca/content/dam/bnc/en/rates-and-analysis/economic-analysis/monthly-economic-monitor.pdf>



employment conditions. Bank of Canada's October Monetary Policy Report suggests similar outlooks, citing the global semiconductors shortage as a key driver of inflation and export slack.

The economic impact of the semiconductor industry is significant. According to the Semiconductor Industry Association (SIA), the semiconductor industry has an employment multiplier of 6.7, meaning that there are a total of 5.7 jobs added across related sectors for each semiconductor job created¹⁰⁴.

Based on SIA's analysis, a USD \$50 billion investment into semiconductor manufacturing would build 10 fabs. Each \$270,270 in investment would create 1 job, and 227,000 temporary and permanent jobs would be created in total over 2021-2027.

In Canada, the jobs multiplier is 1.9 for the ICT Manufacturing industry. From 2016 to 2019, the number of semiconductor jobs has grown at a CAGR of 2.34%. Over the past year, 18% of direct jobs were lost due to pandemic-led wider unemployment and supply chain disruptions.

Since 2018, job growth in semiconductors has already started to slow down¹⁰⁵. Over the past year, 18% of direct employment was lost to supply chain disruptions and the growth in market share of other countries that have focused on semiconductor R&D and capacity-building. If Canada continues on the current path, the number of jobs and amount of GDP directly or indirectly supported by the semiconductor industry will see a downward trend over the next few years, causing a total loss of 22,250 jobs and \$2.4 billion in GDP by 2027.

Alternatively, under different investment scenarios, Canada will see annual additions of temporary jobs to support infrastructure development from 2021 to 2026. Most importantly, in the long-run, as R&D and manufacturing capabilities are established, permanent jobs in the semiconductor industry will be created. Job creation not only has a positive ripple effect on other critical industries and supports economic growth, but also attracts and retains high-skilled talent in Canada. Commitment from the Canadian government positions the sector to also draw private investment and foreign direct investment into Canada.

¹⁰⁴ https://www.semiconductors.org/wp-content/uploads/2021/05/SIA-Impact_May2021-FINAL-May-19-2021_2.pdf

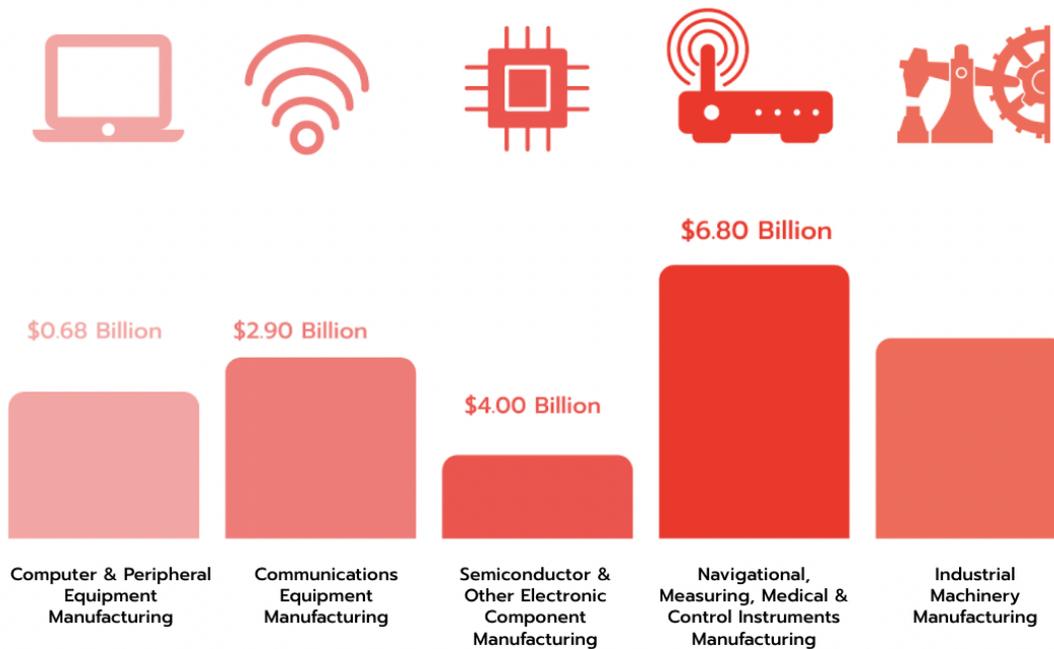
¹⁰⁵ <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610048901>

Semiconductor Sector in Canada

Trade

In 2020, five of the sectors in the Electronics Industry exported a total value of \$18.1 billion in goods, accounting for 3.5% of total Canadian exports.

Canada Electronics Exports (2020)



SOURCE: Canadian Industry Statistics, Statistics Canada, CSC estimates

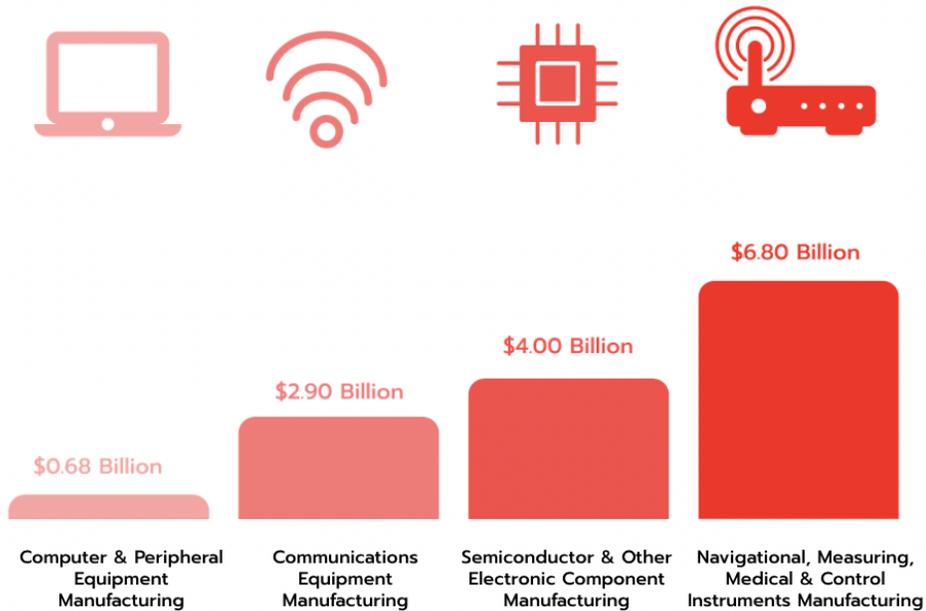
106

¹⁰⁶ Statistics Canada, CSC estimates

Manufacturing Shipments

In 2018, four of the sectors in the Electronics Industry produced a total value of CAD \$14.4 billion goods, of which the Semiconductor and Other Electronic Component Manufacturing sector produced CAD \$4.0 billion (28%).

Canada Electronics Manufacturing Shipments (2018)



SOURCE: Canadian Industry Statistics, Statistics Canada, CSC estimates

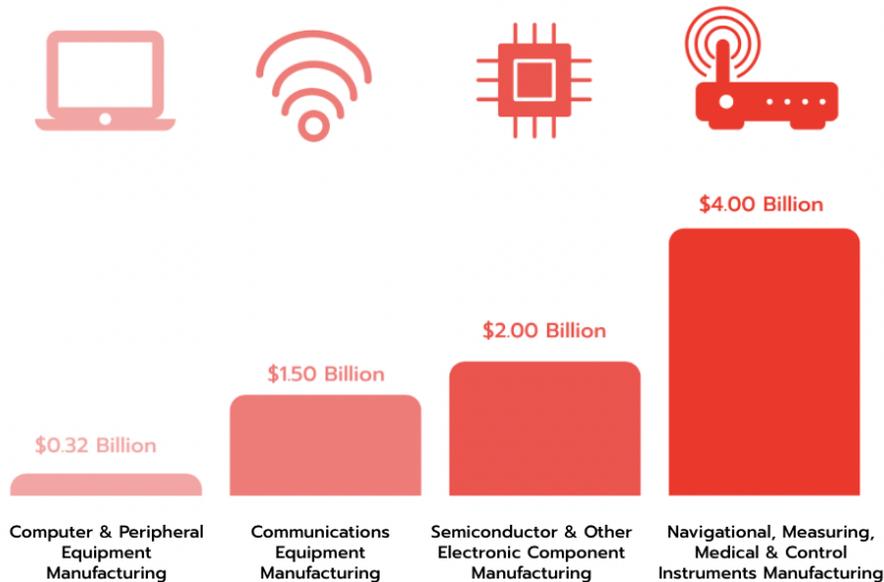
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¹⁰⁷ Canadian Industry Statistics, Statistics Canada, CSC estimates

Value Added Manufacturing

In 2018, four of the sectors in the Electronics industry produced a total manufacturing value added of CAD \$7.8 billion, of which the Semiconductor and Other Electronic Component Manufacturing sector produced CAD \$2.0 billion (26%).

Canada Electronics Manufacturing Value Add (2018)



SOURCE: Canadian Industry Statistics, Statistics Canada, CSC estimates

108

History of Semiconductor Industry in Canada

Canada's semiconductor industry is concentrated in Southern Ontario and Southern Quebec. Global giants such as AMD, Qualcomm, Synopsys, Intel, IBM, Teledyne Dalsa/Micralyne, and Semtech have a strong presence in these regions, many of which have scaled by acquiring smaller Canadian start-ups and companies like Celestica, Snowbush, Altera, Gennum, Micralyne, Dalsa, and ATI Technologies over the past 20 years.

The Canadian semiconductor value chain includes design, testing, and specialized manufacturing, the genesis of which can be traced back to early advances in Ontario, with pioneers from Bell Northern Research, ATI Technologies (AMD), IBM, Gennum (Semtech), and Celestica. The local talent pool attracted other global players like Intel, Qualcomm, and

¹⁰⁸ ibid



Rambus, who also established significant R&D operations. This fueled the growth of leading small- and medium-sized companies that were eventually acquired by these MNEs. Collectively, these firms are global leaders in sensors, memory, high speed and high performance computing, connectivity, cryptography, and communications. These companies include the world's largest semiconductor company by revenue and top patent recipients.

Across Canada, the supply of high-quality local engineering talent, in the forms of both experienced engineers and new graduates, has prompted global multinationals to establish Canadian operations in this region, either through the acquisition of successful homegrown Canadian companies or through the establishment of new R&D sites. Contributing to the "Made in Canada" story, some examples include:

- AMD's \$5.4 billion acquisition of ATI technologies¹⁰⁹; AMD Canada remains headquartered in Markham, and employs over 2,300 people¹¹⁰;
- Intel's expansion of its Canadian footprint in the GTA through the \$16.7 billion¹¹¹ acquisition of Altera¹¹², forming Intel's PSG Canadian Center of Excellence for FPGA design tools, IP, and FPGA architecture, the 3rd largest PSG site globally with more than 200 employees¹¹³ — Intel has over 500 employees in Canada;
- Rambus' acquisition of Snowbush IP¹¹⁴;
- Teledyne Technology's acquisition of DALSA Corporation¹¹⁵ and acquisition of Micralyne¹¹⁶
- Semtech's acquisition of Gennum¹¹⁷

2021: Canada's Current Semiconductor Sector

Currently, Canada's semiconductor capabilities concentrate in design, with both small-to-medium native firms and branches of international players. A scarce few Canadian companies have established foundries or packaging facilities. Continuing to leverage Canada's strength in research and innovation by investing in R&D but also seeking to expand manufacturing capacities will build a more robust supply chain and create high-skilled jobs that retain and attract talent.

¹⁰⁹ <https://www.engadget.com/2006/07/24/amd-buying-ati-for-5-4-billion/>

¹¹⁰ <https://www.amd.com/system/files/documents/cr2020-canada.pdf>

¹¹¹ <http://fortune.com/2015/12/28/intel-completes-altera-acquisition/>

¹¹² <https://newsroom.intel.com/news-releases/intel-completes-acquisition-of-altera/>

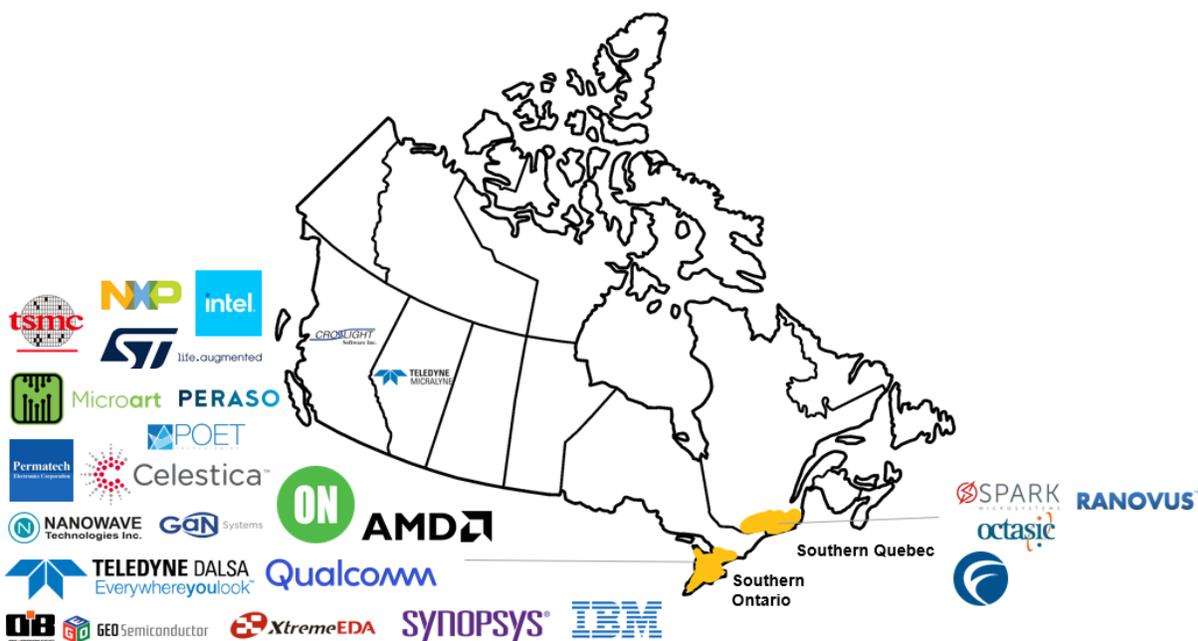
¹¹³ Intel Programmable Solutions Group (PSG)

¹¹⁴ <https://www.rambus.com/rambus-to-acquire-snowbush-ip-assets/>

¹¹⁵ <https://www.teledynedalsa.com/corp/news/276/>

¹¹⁶ <https://www.businesswire.com/news/home/2019093005323/en/Teledyne-Acquires-Micralyne>

¹¹⁷ <http://investors.semtech.com/releasedetail.cfm?ReleaseID=658501>



Southern Ontario is home to highly coveted technical expertise and experience in semiconductors, along with key industrial dependencies in automotive and advanced manufacturing. The province is also a major source of rare earth minerals for EV, EV batteries, and semiconductor manufacturing. On the other hand, Quebec has strategic core expertise in photonics and micro-electromechanical systems (MEMS), such as Centre de Collaboration MiQro Innovation (C2MI). B.C. has a vibrant electronics instrument manufacturing sector and is home to many high tech professionals and research experts. Alberta specializes in MEMS and has highly skilled talent in oil and gas that could be re-skilled to support the advanced manufacturing required for the semiconductor sector.

Teledyne operates production-scale semiconductor manufacturing foundries in Canada (Bromont, QC and Edmonton, AB). ON Semiconductor operates production scale assembly and test facilities in Canada (Burlington, ON) and design engineering in multiple locations in Ontario. Celestica operates its Electronics Testing Lab in Newmarket, ON¹¹⁸ where 7,500 Made-in-Canada ventilators will be built in partnership with Starfish Medical¹¹⁹ and Medtronic¹²⁰. IBM's global lab in Markham, ON is one of the company's major global design and engineering

¹¹⁸ <https://www.celestica.com/our-expertise/services/newmarket-electronics-testing-lab>;

<https://www.newmarkettoday.ca/local-news/celestica-celebrates-grand-opening-at-its-newmarket-facility-1125203>

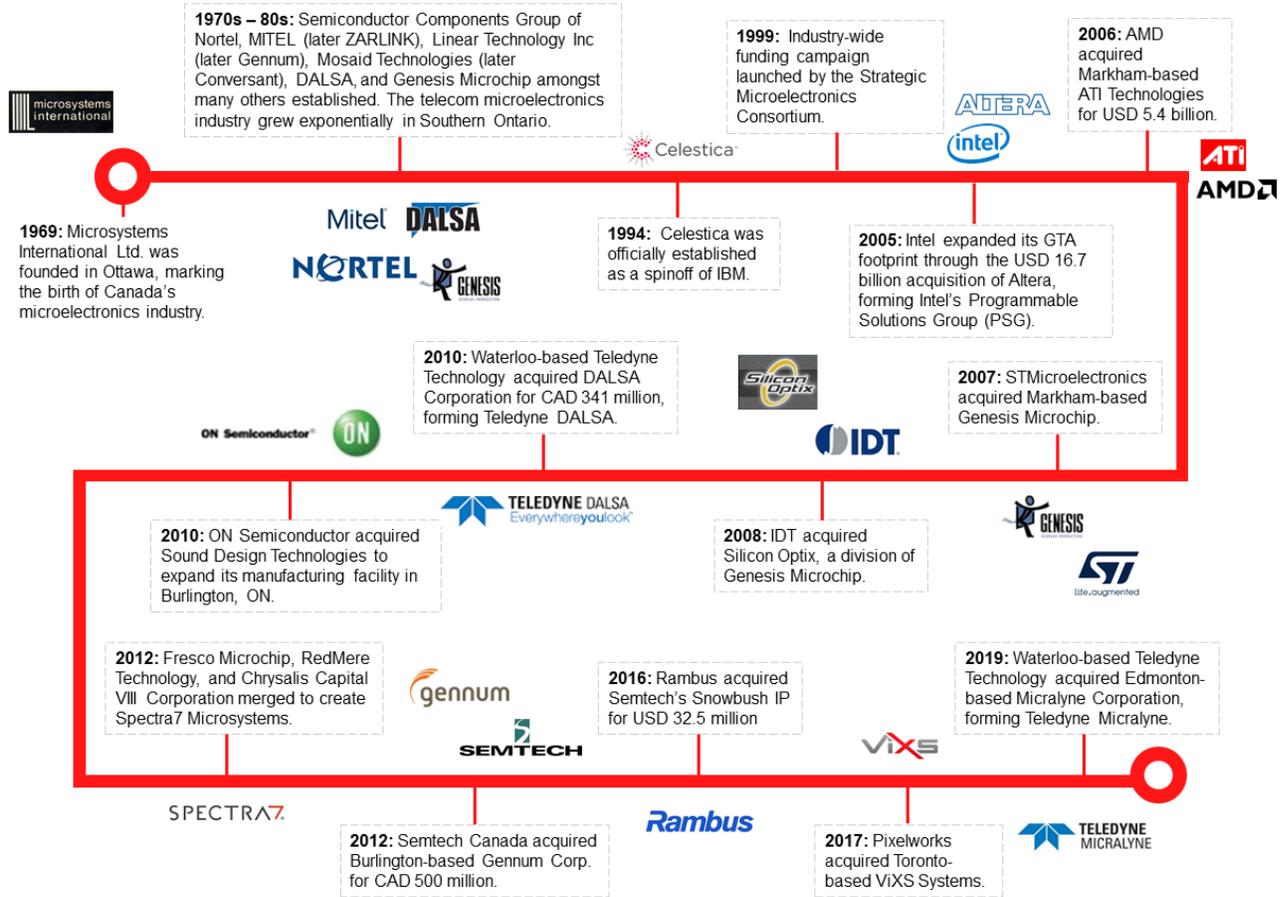
¹¹⁹

<https://corporate.celestica.com/news-releases/news-release-details/celesticas-newmarket-operation-wins-contract-starfish-medical>

¹²⁰

<https://corporate.celestica.com/news-releases/news-release-details/celestica-manufactures-ventilator-components-medtronic-respnse>

locations worldwide and employs thousands. IBM's Bromont, QC plant is the only IBM global semiconductor manufacturing and test facility in the world¹²¹ and "each server developed by IBM contains at least one component built inside" the Bromont facility¹²².



Sources:

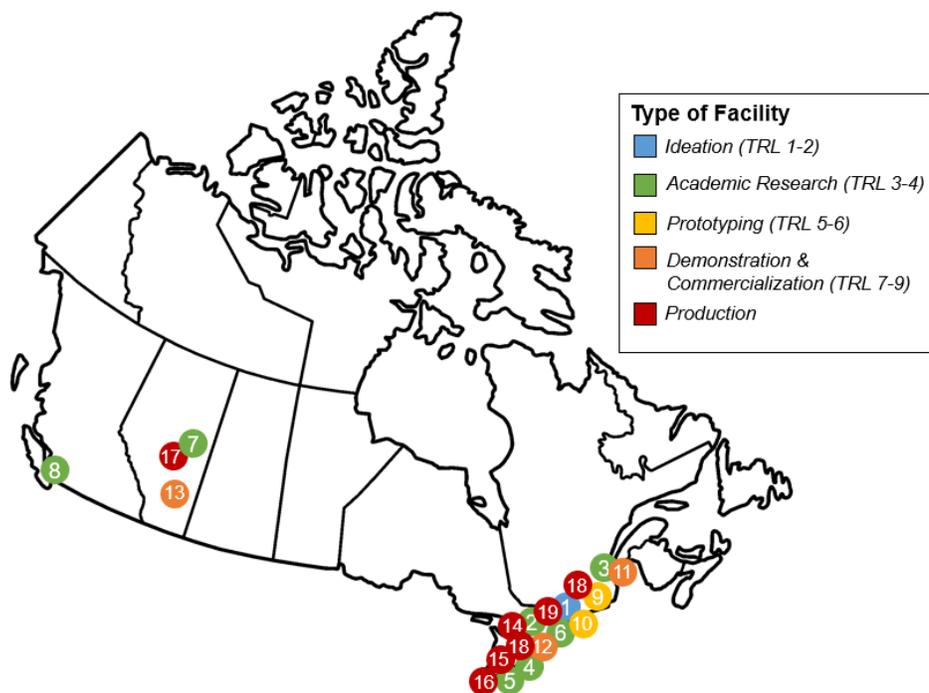
- <https://www.engadget.com/2006/07/24/amd-buying-ati-for-5-4-billion/>
- <https://www.amd.com/system/files/documents/cr2020-canada.pdf>
- <http://fortune.com/2015/12/28/intel-completes-altera-acquisition/>
- <https://newsroom.intel.com/news-releases/intel-completes-acquisition-of-altera/>
- <https://www.rambus.com/rambus-to-acquire-snowbush-ipassets/>
- <https://www.teledynedalsa.com/corp/news/276/>
- <https://www.businesswire.com/news/home/20190903005323/en/TeledyneAcquires-Micralyne>
- <http://investors.semtech.com/releasedetail.cfm?ReleaseID=658501>
- <https://investors.st.com/news-releases/news-releasedetails/stmicroelectronics-completes-acquisition-genesis-microchip>
- <https://www.renesas.com/us/en/about/press-room/idt-acquires-silicon-optixassets-and-technology>
- <https://www.onsemi.com/PowerSolutions/newsItem.do?article=2340>
- <https://www.pnewsire.com/news-releases/redmere-fresco-andleading-investors-partner-to-create-spectra7-backed-by-10-million-in-new-equity-162710076.html>
- <https://www.businesswire.com/news/home/20170802005916/en/Pixelworks-Completes-Acquisition-of-ViXSSystems>
- <https://www.nxp.com/company/about-nxp/worldwidelocations/canada:CANADA>
- <https://itac.ca/uploads/research/07dec.pdf>

¹²¹ <https://www.ibm.com/ibm/ca/en/ibmcanada100/>

¹²² <https://www.ibm.com/ca-en/employment/bromont/>

Canada has several major semiconductor-related ecosystem assets, from research to full scale production aligned to the industry **Technology Readiness Levels** as defined by the Government of Canada¹²³. However, correlated to strong postsecondary enrollment trends, the vast majority of Canadian semiconductor-related assets are focused on academic research and the earliest stages of commercialization.

One ecosystem asset in Canada, ventureLAB's Hardware Catalyst Initiative, is focused primarily on the prototyping, demonstration, and scale commercialization of semiconductor and hardware-related products. This indicates the need to expand and amplify the capacity of the Hardware Catalyst Initiative nationally, to bolster Canada's semiconductor cluster and bridge the gap between research and commercialization at scale. Such an approach complements existing design and prototyping capabilities at C2MI, where the focus is primarily advanced photonics and sensor technologies. Production scale manufacturing capacity is largely in the private sector (Teledyne, IBM).



¹²³ https://buyandsell.gc.ca/sites/buyandsell.gc.ca/files/trl_diagram_0.pdf



TRL 1 to 4 [Ideation and Academic Research]

1. Canadian Microsystems Corporation (CMC)

Montreal, Quebec; Kingston & Ottawa, Ontario

- Not-for-profit organization managing Canada's National Design Network (CNDN)
- A national network of 60 academic partners, 10,000 researchers and 1,000 companies developing innovations in micro-nanotechnologies
- 500 academic-industry collaborations and 20 startups enabled annually

*** NSERC Computing Hardware for Emerging Intelligent Sensing Applications (COHESA) Network**

- "A partnership of 19 Canadian academic research groups across 7 Universities, 6 industry R&D groups and 3 supporting organizations with an emphasis on computing hardware design"
- "Aims to advance the state-of-the-art in computing systems for Machine Learning based intelligent sensing applications (ISAs)"¹²⁴

*** NSERC Canadian Robotics Network**

- A national framework for 11 research groups from 8 Canadian universities, 9 industrial partners, 3 government agencies, and 5 international partners
- Aims "to advance mobile robot systems and human-robot interaction technologies by using learning-based approaches to achieve new levels of performance"¹²⁵

2. Giga-to-Nanoelectronics Centre (G2N)

University of Waterloo, Ontario

- Opened in 2005
- "On-campus microfabrication facility offering a wide range of capabilities for processing electronic materials and devices"¹²⁶

3. Communications and Microelectronic Integration Lab (LACIME)

École de technologie supérieure, Québec

- Research activities aimed to improve communications and telecommunications by optimally using microelectronics

4. Toronto Nanofabrication Centre

University of Toronto, Ontario

- Opened in 2003
- 5,500 square foot facility supporting a wide range of silicon-based fabrication and nanolithography activities
- Key research areas include Microelectronics, MEMS/NEMS, Photonics, etc.

¹²⁴ https://www.nserc-crsng.gc.ca/Business-Entreprise/How-Comment/Networks-Reseaux/COmputing_eng.asp

¹²⁵ https://www.nserc-crsng.gc.ca/Business-Entreprise/How-Comment/Networks-Reseaux/BIN-RVE_eng.asp

¹²⁶ <https://uwaterloo.ca/giga-to-nanoelectronics-centre/>

5. Centre for Emerging Device Technologies (CEDT)

McMaster University, Ontario

- Established in 1987
- Facilitates study “of the optical, electrical, mechanical, and biological properties of semiconductors and related technologies”¹²⁷

6. Nano Fabrication Kingston (NFK)

Kingston, Ontario

- Established “in 2015 as a collaboration between Queen’s University and CMC Microsystems”¹²⁸
- “Leading-edge equipment, methodologies and expertise for designing and prototyping microsystems and nanotechnologies”¹²⁹

7. Fabrication & Characterization Centre (nanoFAB)

University of Alberta, Alberta

- “National, open-access training, service, and collaboration centre, focused on academic and industrial applications in micro- and nanoscale fabrication and characterization”
- 25,000 square foot communal laboratory space with \$84M in over 200 pieces of specialized equipment and infrastructure
- “Complete capabilities for microscopy, spectroscopy, material analysis, lithography, thin-film deposition, etching, and fabrication for MEMS, sensors,” microfluidics, and photonics¹³⁰

8. The Canadian Silicon Photonics Collaborative Research and Training Program (SiEPIC)

University of British Columbia, British Columbia

- “To date, trained over 500 students from 41 different universities in the discipline of ICT systems that involves miniaturization of optical components onto silicon chips”
- “The Silicon Electronics-Photonics Integrated Circuits Fabrication (SiEPICfab) consortium brings together 17 companies and 6 universities to provide research and fabrication capabilities, and accelerate the silicon photonics development cycle.”¹³¹

TRL 5 to 6 [Prototyping]

9. Centre de Collaboration MiQro Innovation (C2MI)

Bromont, Québec

- Opened in 2012
- Fosters collaboration between academic and industrial sectors to accelerate commercialization of value-added products
- \$218M total initial investment
- 532 innovation projects and 118 IPs created to date

¹²⁷ https://trilliummfg.ca/ecosystem_partners/centre-for-emerging-device-technologies-cedt/

¹²⁸ <https://nanofabkingston.ca/about/>

¹²⁹ <https://www.chem.queensu.ca/facilities/nanofabrication-kingston>

¹³⁰ <https://www.nanofab.ualberta.ca/>

¹³¹ <http://siepic.ca/education/>



10. NRC Advanced Electronics and Photonics Research Centre

Ottawa, Ontario

- Research on photonics, electronics, communication and sensor technologies
- Manages the **Canadian Photonics Fabrication Centre (CPFC)** — 40,000 square foot facility with foundry, design, modelling, test, and characterization services

Other related NRC facilities include the Security and Disruptive Technologies Research Centre and Nanotechnology Research Centre

TRL 7 to 9 [Demonstration and Commercialization]

11. Institut national d'optique (INO)

Québec City, Québec

- Opened in 1988, located in the Québec Metro High Tech Park
- “Largest centre of expertise in optics and photonics in Canada”
- Created “75 technology transfers to the industry and 35 spin-off companies” to-date¹³²

12. Hardware Catalyst Initiative (HCI) and Lab

ventureLAB, Markham, Ontario

- Opened in 2020, with more than 25 global partners including TSMC, Arm, Synopsys, AMD, Keysight, IBM & others
- Canada's first and only lab and incubator for founders building hardware and semiconductor-focused products, the only independent facility of its kind in North America
- 2,200+ square foot facility with \$7M in testing, prototyping, production equipment
- The largest centre of technical and manufacturing expertise in Canada in building semiconductors and related products to full production
- More than \$40 million in equipment, manufacturing expertise, design tools contributed by industry leaders including AMD, Arm, TSMC, Keysight, Synopsys, IBM to match nearly \$10M in funding from the Government of Canada through FedDev Ontario.

13. ACAMP

Calgary, Alberta

- Established “in 2007 as an industry-led advanced technology product development centre for entrepreneurs to move their innovation from proof-of-concept to manufactured product”
- “Focus on electronics hardware, firmware, software (machine learning and AI), sensors, and embedded systems”
- “14,000 square foot facility with over \$15 million in specialized product development equipment”
- Helped 440 clients to date, with 120 projects and \$500 million client revenue annually¹³³

¹³² <https://www.ino.ca/>

¹³³ <https://www.acamp.ca/>

High Volume, Commercial Production Manufacturing Capabilities

14. Teledyne DALSA (previously Teledyne)

Bromont, Québec

- #1 Independent Pure-Play MEMS Foundry Worldwide
- 41,000 square foot facility with 200 mm and 150 mm wafer capabilities
- 1,000 employees
- Formed through acquisition of DALSA by Canadian company Teledyne Technologies in 2010

15. ON Semiconductor

Burlington, Ontario

- 94,000 square foot assembly / test factory
- Miniaturized SiPs / Hybrids / MCMs using 3D Chip Stacking
- Acquired Sound Design Technologies in 2010

16. Semtech Canada (previously Gennum Corp.)

Burlington, Ontario

- 400 employees in Canada
- Acquired Gennum Corporation in 2012

17. Teledyne Micralyne (previously Teledyne)

Edmonton, Alberta

- 55,000 square foot facility
- Wafer processing, packaging and assembly capabilities
- Formed through acquisition of Micralyne by Teledyne Tech. in 2019

18. IBM

Bromont, Québec and Markham, Ontario

- IBM Bromont “was established in 1972 and is the only IBM semiconductor manufacturing and testing facility in the world. Each server developed by IBM contains at least one component built inside the Bromont plant.”¹³⁴
- IBM Markham Lab is one of the largest development sites for IBM globally, employing 3,000 developers and Top 10 Corporate R&D Spender in Canada^{135,136, 137}

19. Celestica

Newmarket, Ontario

- Celestica's Newmarket Microelectronics Lab and Electronics Testing Lab offer cutting edge design, assembly, and testing solutions to clients
- One of the leading electronics manufacturing services company in Canada and the world, Celestica employed 20,500 people in 2020

¹³⁴ <https://www.ibm.com/ca-en/employment/bromont/>

¹³⁵

<https://www.itworldcanada.com/article/ibm-canadas-new-president-wants-big-blue-to-be-your-digital-transformation-partner/406304>

¹³⁶ <https://researchinfosource.com/top-100-corporate-rd-spenders/2020/list>

¹³⁷ <https://www.ibm.com/ibm/ca/en/ibmcanada100/>



Canada’s Strengths and Weaknesses: Semiconductor Supply Chain

“Canada has all the end markets that people can tap into but lacks the ability to deliver the goods to it.” - Jim Seto, CEO, ePIC Blockchain; past Corporate VP, Foundry Operations, AMD

Canada has made significant investments in strategic areas to drive economic growth, including Artificial Intelligence, Quantum Computing, Clean Tech, Critical Minerals, and more. Billions of dollars have been invested into the sectors, which cannot thrive without investing in all elements of the supply chain — especially Canada’s semiconductor industry.

Semiconductor-reliant Sector	Recent Federal Investments
AI	\$125 million Pan-Canadian Artificial Intelligence Strategy ¹³⁸ \$1 billion in government funding awards \$1.2 billion of planned government investments have been publicly announced for Québec ¹³⁹
Quantum Computing	\$360 million commitment to launch a National Quantum Strategy ¹⁴⁰ \$40 million contribution through the Strategic Innovation Fund to D-Wave Systems Inc. ¹⁴¹
Clean Tech	\$8 billion through Net Zero Accelerator \$1 billion to support private sector investment in cleantech projects ¹⁴²
Critical Minerals	Investing \$250 million in innovative, early-stage companies through the Industrial Research Assistance Program

¹³⁸ <https://www.investcanada.ca/programs-incentives/pan-canadian-ai-strategy>

¹³⁹ https://www.mcgill.ca/centre-montreal/files/centre-montreal/aipolicyandfunding_report_updated_mar5.pdf

¹⁴⁰

<https://www.canada.ca/en/innovation-science-economic-development/news/2021/07/government-of-canada-launches-public-consultations-on-national-quantum-strategy.html>

¹⁴¹

<https://www.canada.ca/en/innovation-science-economic-development/news/2021/03/government-of-canada-contribution-strengthens-canadas-position-as-a-global-leader-in-quantum-computing.html>

¹⁴² <https://www.investcanada.ca/industries/cleantech>



Artificial Intelligence

The growth of artificial intelligence (AI) — the ability of a machine to perform cognitive functions associated with human minds — presents significant opportunities and demand for semiconductors. Many AI applications, McKinsey reports, are reliant on hardware “as a core enabler of innovation, especially for logic, computation, networking, storage and memory functions.”¹⁴³ McKinsey estimates AI-related semiconductors to see growth of 18% annually, and by 2025, AI-related semiconductors could account for 20% of all demand¹⁴⁴. The supply of semiconductors is critical to the continued growth of AI technologies and continued innovation in semiconductors is paramount to keep up with the pace of AI development.

Quantum Computing

Quantum computing is another “transformative technology in which Canadian researchers, businesses and workers have developed a leading global advantage”¹⁴⁵. It has important applications in security, optimization, drug and material design, and simulation of physical, chemical and biological processes. While the concept of a quantum computer has been theorized long ago, it has only been brought to life by semiconductors. Globally, the “quantum computing market is expected to grow to \$50 billion by 2030”¹⁴⁶.

Clean Tech

Semiconductors play a key role in clean tech, serving as the basis for solar electric energy systems, wind turbines, and other electric equipment used in the renewable energy supply chain. Semiconductors are also becoming increasingly important in making the electric grid more intelligent through the use of smart meters, sensors, wireless communications, and control systems. The use of semiconductors in clean tech is crucial to Canada’s transition to a low-emission economy. There are over a thousand companies in the Canadian cleantech sector, and Canada ranks #2 in the global cleantech innovation index. Clean tech accounted for 3% of Canada’s GDP in 2019 and employed 341,000 people¹⁴⁷. Canada is also a world leader in clean

¹⁴³

<https://www.mckinsey.com/industries/semiconductors/our-insights/artificial-intelligence-hardware-new-opportunities-for-semiconduct-or-companies>

¹⁴⁴

<https://www.mckinsey.com/industries/semiconductors/our-insights/artificial-intelligence-hardware-new-opportunities-for-semiconduct-or-companies>

¹⁴⁵

<https://www.newswire.ca/news-releases/government-of-canada-contribution-strengthens-canada-s-position-as-a-global-leader-in-quantum-computing-824210415.html>

¹⁴⁶Ibid.

¹⁴⁷ <https://www.investcanada.ca/industries/cleantech>



energy production in particular, ranking 7th (3% of world production) in 2018, with 16.3% of the country's total energy production coming from renewables¹⁴⁸.

Critical Minerals

As Natural Resources Canada indicates, "critical minerals are the building blocks for the clean and digitized economy."¹⁴⁹ They are vital to semiconductors manufacturing supply chains and related technologies including clean tech, defence and security equipment, consumer electronics, agriculture, medical applications and critical infrastructure. The Canadian government has developed a list of 31 minerals that are critical to the sustainable economic success of Canada and position Canada as the leading mining nation, as set out in the Canadian Minerals and Metals Plan (CMMP)¹⁵⁰.

Chemicals

The semiconductor sector and more broadly the electronics industry uses a wide range of chemicals including etchants used in wafer manufacturing, cleaning agents and chemicals, solvents and high purity process chemicals, different types of acids and bases and materials such as solder used on printed circuit boards that can house multiple chips and components embedded in products ranging from automobiles to washing machines to tablets and mobile phones¹⁵¹.

Global Semiconductor Incentives & Policy

The world leaders for semiconductor companies can be narrowed down to a few nations. These countries are top manufacturers and innovators, whose governments offer heavy investments, incentives, and grants. Higher public investment has been associated with significant market growth in these regions. For instance, from 2000 to 2020, the Chinese government invested approximately \$50 billion in the industry, resulting in an annual CAGR of 15.7%¹⁵². Global supply chain vulnerabilities revealed by the pandemic also led governments to pledge large-scale programs, including the U.S. government's Infrastructure Plan (\$52 billion semiconductor industry aid) and the EU's €145 billion Recovery and Resilience Fund. Below is a chart illustrating examples of policies and incentives of select countries to stimulate the semiconductor industry.

¹⁴⁸ <https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/renewable-energy-facts/20069>

¹⁴⁹ <https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/critical-minerals/23414>

¹⁵⁰ *ibid.*

¹⁵¹ <https://cen.acs.org/articles/95/i40/computer-chips-shrink-cleaning-needs.html>

¹⁵²

<https://www.semiconductors.org/wp-content/uploads/2020/07/U.S.-Needs-Greater-Semiconductor-Manufacturing-Incentives-Infographic.pdf>

Case Study: The Economic Impacts of \$50 Billion in Chip Incentives

In a study by Oxford Economics and the Semiconductor Industry Association¹⁵³, it was found that the creation of \$50 billion in federal incentives for the semiconductor industry would create 42,000 new permanent semiconductor jobs by 2027. It would also incentivize U.S. semiconductor manufacturing to add \$24.6 billion annually to the U.S. economy and create an average of 185,000 temporary jobs annually from 2021 to 2026.

Furthermore, an incentive program would build up the U.S. semiconductor industrial infrastructure, which will have an enduring positive impact on the U.S. economy, jobs, and industries. In 2020, over 300 different industries out of 546 in the U.S. economy made \$86.1 billion in purchases from the semiconductor industry, not to mention industries that indirectly rely on semiconductors (e.g. electronic products and subsystems enabled by semiconductors). Nearly all sectors of the economy would experience downstream benefits of semiconductor incentives and policies, directly or indirectly. The \$50-billion investment would help create an estimated 10 additional fabs in the U.S. The semiconductor industry growth would also translate into additional ripple effects. For instance, using the 2020 U.S. semiconductors job multiplier of 6.7, the semiconductor industry would support approximately 2.13 million jobs in the U.S. economy in 2027, an increase of 280,000 from the 2020 total of 1.85 million.

The study concludes that, during this six-year period, “the cumulative annual impact of such an incentive program on GDP and jobs would be \$147.7 billion and 1.1 million, respectively,” combining all channels of economic impact — direct, indirect, and induced.

These policies have attracted leading MNEs to build new manufacturing facilities or expand existing ones in the respective countries. What follows are case studies of recent announcements by global companies:

Company	Country	Incentives/Policies	Expected/Realized Outcomes
		(\$52 billion in semiconductor industry aid)	2 new semiconductor manufacturing facilities that will cost \$20 billion USD, creating 21,000 jobs in Arizona
		Tax-Exempt Industrial Revenue Bonds for Manufacturing Projects, State Sales and Use Tax Refund Program, Texas-specific programs	4 new facilities, including a \$17 billion factory in Texas that will create 1,800 jobs, asking for \$1 billion in tax incentives
		(\$52 billion in semiconductor industry aid)	Announced \$1.4 billion to expand manufacturing capacity at 3 existing locations

¹⁵³ https://www.semiconductors.org/wp-content/uploads/2021/05/SIA-Impact_May2021-FINAL-May-19-2021_2.pdf



Arizona state \$200 million in infrastructure development support

New \$12 billion fab in Arizona to start in 2021



(€145 billion Recovery and Resilience Fund, €1.75 billion IPCEI on Microelectronics)

Announced \$1.4 billion to expand manufacturing capacity at 3 existing locations, including its site in Germany



SAMSUNG



(€145 billion Recovery and Resilience Fund, €1.75 billion IPCEI on Microelectronics)

Weighing deal with TSMC or Samsung for a new foundry



(Law for the Encouragement of Capital Investment, R&D and IP Development Grants)

New \$11 billion fab that will create 1,000 jobs, applying for \$1 billion in grants from the Israeli government



Singapore Economic Development Board partnership, with customer investments

\$4 billion investment in new fab on the Globalfoundries campus in Singapore

Canada's Global Trade Relationships

Canada relies heavily on other nations for semiconductor manufacturing; the impact of COVID-19 has highlighted this major gap and risk.

Canada can leverage its strong reputation for reinforcing rules-based international order with major trading partners and agreements in place, including with the US via CUSMA, the EU through CETA, and the Asia-Pacific region (South Korea, Taiwan, Malaysia, Singapore) through CPTPP.

Country	Trade Agreement	Key Policies
 <p>Leader across value chain activities with highest market share in many</p>	<p>Canada United States Mexico Agreement (CUSMA)</p>	<ul style="list-style-type: none"> - Stronger IP protections including bans on the forced disclosure of sensitive IP like source code, algorithms and other proprietary technical data - New commitments to protect the free and open flow of data¹⁵⁴
 <p>High commitment to industry growth with strong market share</p>	<p>Canada-European Union Comprehensive Economic and Trade Agreement (CETA)</p>	<ul style="list-style-type: none"> - Preferential access to key European markets - Eliminates tariffs and reduces barriers across most sectors - Easier for certain skilled professionals to work in the other region¹⁵⁵
 <p>Large market with some capacity</p>	<p>Canada-United Kingdom Trade Continuity Agreement (TCA)</p>	<ul style="list-style-type: none"> - Preferential access to the U.K. market with 98% of tariffs eliminated - Access to procurement opportunities with the UK government - Promotion of mutual FDI opportunities¹⁵⁶
 <p>Major market with manufacturing capabilities</p>	<p>Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP)</p>	<ul style="list-style-type: none"> - Preferential access to key markets in the Asia-Pacific region, with reduced tariffs - University and research links and exchanges (including NSERC programs)¹⁵⁷
 <p>Major market with manufacturing capabilities</p>	<p>Canada-Korea Free Trade Agreement (CKFTA)</p>	<ul style="list-style-type: none"> - Will “boost Canada’s GDP by \$1.7 billion and increase Canadian exports to Korea by over 30%” - Preferential market access with eliminated tariffs - Promotion of mutual FDI opportunities¹⁵⁸

¹⁵⁴ <http://www.usmcoalition.org/wp-content/uploads/2019/04/USMCA-Fact-Sheet-SIA.pdf>

¹⁵⁵

https://www.international.gc.ca/trade-commerce/trade-agreements-accords-commerciaux/agr-acc/ceta-aecg/ceta_explained-aecg_a_percu.aspx?lang=eng

¹⁵⁶

<https://www.international.gc.ca/trade-commerce/trade-agreements-accords-commerciaux/agr-acc/cuktca-accru/trade-agreement-explained.aspx?lang=eng>

¹⁵⁷ https://www.canadainternational.gc.ca/japan-japon/bilateral_relations_bilaterales/index.aspx?lang=eng

¹⁵⁸ <https://www.tradecommissioner.gc.ca/korea-republic-coree-republique/157174.aspx?lang=eng>



Country	Trade Agreement	Key Policies
 <p>Increasing market share and high commitment to growth</p>	<p>Canada-China Promotion and Reciprocal Protection of Investments Agreement (FIPA)</p>	<ul style="list-style-type: none"> - Shifting trade and international relations with Canada and other G20 nations - Students from India and China represent more than 50% of international students according to Global Affairs¹⁵⁹
 <p>Commitment to industry growth</p>	<p>Canada-Israel Free Trade Agreement (CIFTA)</p>	<ul style="list-style-type: none"> - Science and technology are significant economic drivers in Israel - Support for Canada's inclusive trade approach (gender equality, small and medium-sized enterprises, and corporate social responsibility) - Improved market access¹⁶⁰
 <p>Commitment to industry growth, largest U.S. semiconductor trading partner¹⁶¹</p>	<p>Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP)</p>	<ul style="list-style-type: none"> - Trade and investment opportunities in clean technologies, information and communications technology, aerospace, and infrastructure - Student recruitment and academic partnership opportunities¹⁶²
 <p>Leader across value chain, especially in manufacturing and design</p>	<p>Product-specific bilateral agreements, APEC, WTO</p>	<ul style="list-style-type: none"> - Top 3 imports: wired or wireless network communication equipment, automatic data processors, integrated circuits¹⁶³ - Priority sectors include: information and communications technology, biotechnology, clean technologies¹⁶⁴

The recent White House 100-Day Review¹⁶⁵ identifies U.S. semiconductor supply chain strengths and opportunities. With the U.S. strengths in semiconductor manufacturing, Canada has an opportunity to develop a strategic trade agreement specific to the semiconductor supply chain to strengthen its vulnerabilities.

¹⁵⁹ <https://www.international.gc.ca/education/strategy-2019-2024-strategie.aspx?lang=eng>

¹⁶⁰

<https://www.international.gc.ca/trade-commerce/trade-agreements-accords-commerciaux/agr-acc/israel/fta-ale/index.aspx?lang=eng>

¹⁶¹ https://www.semiconductors.org/wp-content/uploads/2021/06/SIA_Letter_to_Malaysia_Govt_May_28_.pdf

¹⁶²

<https://www.international.gc.ca/trade-commerce/trade-agreements-accords-commerciaux/agr-acc/cptpp-ptpgp/countries-pays/malaysia-malaisie.aspx?lang=eng>

¹⁶³ https://www.roc-taiwan.org/ca_en/post/12715.html

¹⁶⁴ <https://www.international.gc.ca/world-monde/taiwan/relations.aspx?lang=eng>

¹⁶⁵ <https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf>



Canada's Workforce

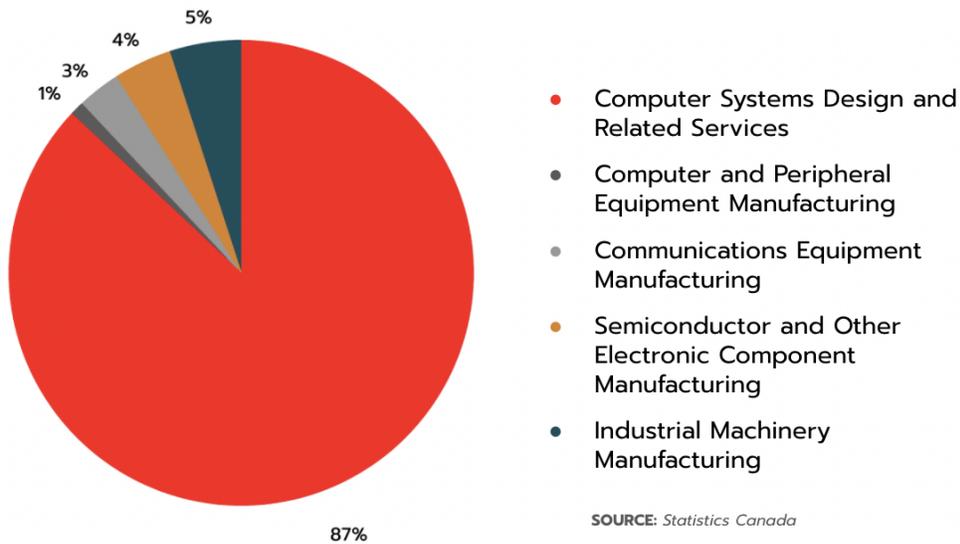
In Canada, there are over 13,000 businesses employing close to 320,000 Canadians in direct electronics-related industries that create at least 2,000,000 indirect and direct jobs.

Electronic Instrument Employment in Canada (2020)				
NAICS Code	Industry	# of Businesses	# of jobs	Average Annual salary
3331	Agricultural, construction and mining machinery manufacturing	1,450	24,715	\$84,968.64
333A	Industrial, commercial and service industry machinery manufacturing	N/A	37,095	N/A
3336	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	744	16,940	\$55,118.06
335	Electrical equipment, appliance and component manufacturing	2,167	34,370	\$64,009.31
3364	Aerospace product and parts manufacturing	2,522	18,350	\$65,395.10
3391	Medical equipment and supplies manufacturing	2,522	18,350	\$65,395.10
517	Telecommunications	5,951	128,674	N/A
	TOTAL	13,538	314,235	\$68,913.23

SOURCE: Canadian Industry Statistics, Statistics Canada, CSC estimates

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¹⁶⁶ Canadian Industry Statistics, Statistics Canada, CSC estimates

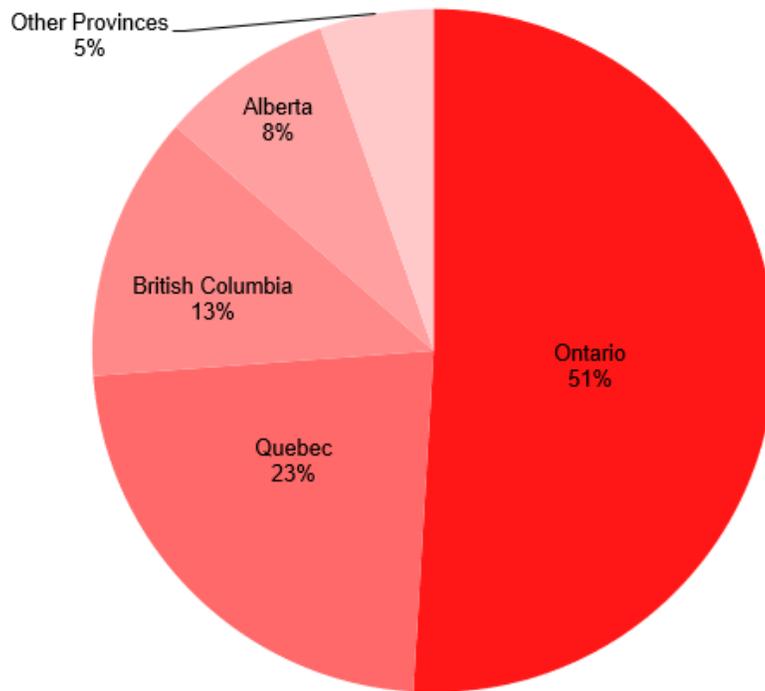


In 2020, five of the sectors in the Electronics Industry employed 369,930 people, of which Computer Systems Design and Related Services accounted the most (87%), followed by Industrial Machinery Manufacturing (5%) and Semiconductor and Other Component Manufacturing (4%). According to the Semiconductor Industry Association, semiconductor jobs have a multiplier of 5.89. As such, Canada's semiconductor sector creates close to 2 million indirect and direct jobs that are critical to our most strategic economic sectors of automotive, energy, health, agriculture, and advanced manufacturing and the underpinning for every digitally enabled industry.

Workforce Geographic Breakdown by Top Provinces

Electronics-related employment is concentrated in Ontario, Quebec, British Columbia, and Alberta, with Ontario accounting for over half (51%) of all Canadian electronics-related employment, followed by Quebec (23%).

Top Provinces by Electronics-Related Employment (2020)



Source: StatsCan

<https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610048901>

With over 270,000 electronics-related jobs (74%) based in Ontario and Quebec, retaining and creating new jobs in this sector is critical to the long-term competitiveness and growth of Canada's automotive, health, mining, advanced manufacturing, and other sectors.



Electronics-Related Employment in Top Canadian Provinces (2020)						
NAICS Code	Industry	Ontario	Quebec	British Columbia	Alberta	Other Provinces
3341	Computer & Peripheral Equipment Manufacturing	950	750	1625	80	(890)
3342	Communications Equipment Manufacturing	8,695	2,650	165	480	1,095
3344	Semiconductor & Other Electric Component Manufacturing	8,685	4,150	1,435	1,130	355
3332	Industrial Machinery Manufacturing	9,160	5,795	1,380	595	1,010
5415	Computer Systems Design & Related Services	160,990	71,285	41,830	28,185	18,345
	TOTAL	188,480	84,630	46,435	30,470	19,915

SOURCE: Canadian Industry Statistics, Statistics Canada, CSC estimates

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Electronics-related employment accounted for 1.89% of total Canadian jobs in 2018. The map below identifies the provinces and regions with above-average specializations in semiconductor and electronic manufacturing. Labour force concentration is determined relative to the size of the local labour force. Provinces and regions are compared against the national percentage using the Location Quotient (local percentage divided by national percentage). Locations with significant workforce concentrations in electronics-related sectors are ranked as moderate (LQ = 0.7-1.0), above average (LQ = 1.0-2.0), or high (LQ > 2.0). Furthermore, the top sectors for each location are identified in text.

¹⁶⁷ Statistics Canada

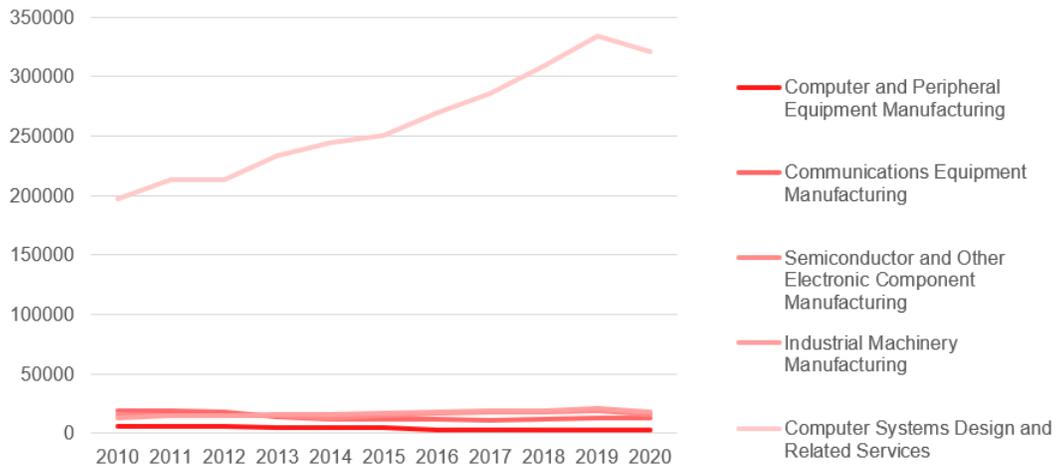


Workforce 10-year Employment Trends

Overall, employment in the electronics industry increased at a CAGR of 3.93% per year from 2010 to 2020. The Computer Systems Design and Related Services sector saw the highest growth rate (5.96%), followed by Industrial Machinery Manufacturing (3.00%). Semiconductor and Other Electronic Component Manufacturing experienced a growth rate of 0.26% per year, whereas employment declined in Computer and Peripheral Equipment Manufacturing (CAGR -8.63%) and Communications Equipment Manufacturing (CAGR -3.68%).

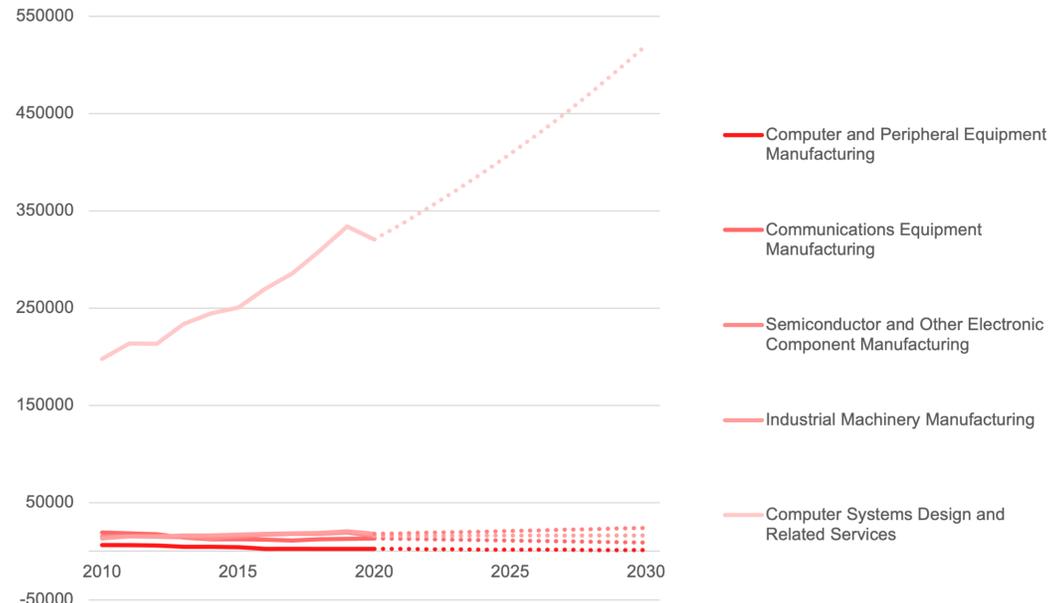


Canada 10-Year Employment Trends by Sector, 2010-2020



Source: StatsCan
<https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610048901>

Canada 10-Year Employment Trends by Sector, 2010-2030



Source: Council estimates based on 2021-2030 numbers forecasted using 2010-2020 CAGR



Semiconductor Demand in Key Canadian Industries

Life Sciences & Healthcare

Ageing demographics, the COVID-19 pandemic, and global trends shifting towards ICT and advanced technologies will continue to drive demand for medical devices, presenting opportunities and making the sector critical to the Canadian economy and overall innovation landscape. Canada has an estimated US\$6.7 billion medical device market, accounting for about 1.9% of the global market (2017). The Medical Equipment and Supplies Manufacturing industry contributes over 21,000 direct jobs and \$2.22 billion GDP to the Canadian economy. With 2,522 establishments, the sector saw \$3.6 billion in manufacturing revenue and \$2.3 billion in value-added in 2017. Challenges facing the industry include declining exports from 2017 to 2019 and a resulting increase in trade gaps.¹⁶⁸

Telecommunications, 5G and Satellite Communications

The telecommunications industry benefits a majority of consumers in Canada and globally, with products being introduced on a yearly basis that further drive the dependency on telecommunication companies. The evolution of communicative devices over the past decade is phenomenal, making the once one-sided cellphone into a super computer powered by semiconductor technology.

Canada is a global leader in the R&D “and manufacturing of satellite subsystems and components, and the operation of communications satellites.” Satellite technologies can enable delivery of vital public services like distance learning and telemedicine, and connect devices and people through the Internet of Things. The Canadian government is committed to investing in satellite communications. Budget 2018 provided \$100 million through the Strategic Innovation Fund (SIF) to satellite technologies R&D, with new investments announced in subsequent years¹⁶⁹. The telecommunications, 5G, and Satellite Communications industry is one of the top purchasers of semiconductors. Advancements and growth in 5G and satellite technologies present a demand spike for semiconductors in the near future.

Semiconductor technology is essential in powering this fiscally crucial industry. The telecommunications industry contributed over \$74 billion in GDP to Canada's economy¹⁷⁰ and

¹⁶⁸ https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01736.html

¹⁶⁹ https://www.ic.gc.ca/eic/site/082.nsf/eng/h_04013.html

¹⁷⁰ https://www.cwta.ca/wp-content/uploads/2020/12/EN_Investing_in_Canadas_Digital_Infrastructure.pdf



supported well over 600,000 jobs in 2019 alone¹⁷¹. The growth of the industry is astronomical, estimating the value chain alone to contribute approximately \$200 billion in GDP to the Canadian economy over the next five years.

Cybersecurity and Data

Internet of Things (IoT) devices have rapidly taken hold in a wide range of industries. The rapid growth of IoT dependency underscores the importance of a reliable hardware focused security program. Software security alone is not sufficient; hardware based cybersecurity systems are harder to hack, which protects the investments and competitive innovations of Canadians¹⁷².

Incorporating semiconductors in cybersecurity is proven to be a more secure avenue. According to *Semiconductor Engineering*, a “silicon-based root of trust” offers “a range of robust security options for IoT devices, including secure connectivity between the IoT device and its cloud service,”¹⁷³ as well as security lifecycle management. This feature allows service providers and OEMs to control the security aspects of IoT devices when in operation. The most competitive Canadian industries are relying more heavily on IoT devices, like automotive, medical and agriculture, security breaches could have serious consequences, including heavy financial damage and threat to national security.

Energy

There are over a thousand companies in the Canadian cleantech sector, and Canada ranks #2 in the global cleantech innovation index. Clean tech accounted for 3% of Canada's GDP in 2019 and employed 341,000 people. Canada is also a world leader in clean energy production in particular, ranking 7th (3% of world production) in 2018, with 16.3% of the country's total energy production coming from renewables¹⁷⁴.

Consistent government and private investments in the area has propelled the industry's outstanding growth. Between 2016 and 2020, 65 investment announcements were made. As a part of the Strategic Innovation Fund, “the Net Zero Accelerator allocates \$8 billion over 7 years to expedite decarbonization projects...and accelerate Canada's industrial transformation.” Additional support for innovative projects across all sectors amounts to \$1 billion, to support private sector investment in cleantech projects. The Canadian government also provides incentives to the industry through programs including the Clean Growth Hub, Accelerated Capital Cost Allowance (ACCA), Scientific Research and Experimental Development (SR&ED).

¹⁷¹

<https://www.newswire.ca/news-releases/telecommunications-industry-directly-contributes-74-5-billion-annually-to-canada-s-economy-and-supports-638-000-jobs-according-to-new-report-838955027.html>

¹⁷² <https://semiengineering.com/what-does-cybersecurity-have-to-do-with-semiconductors/>

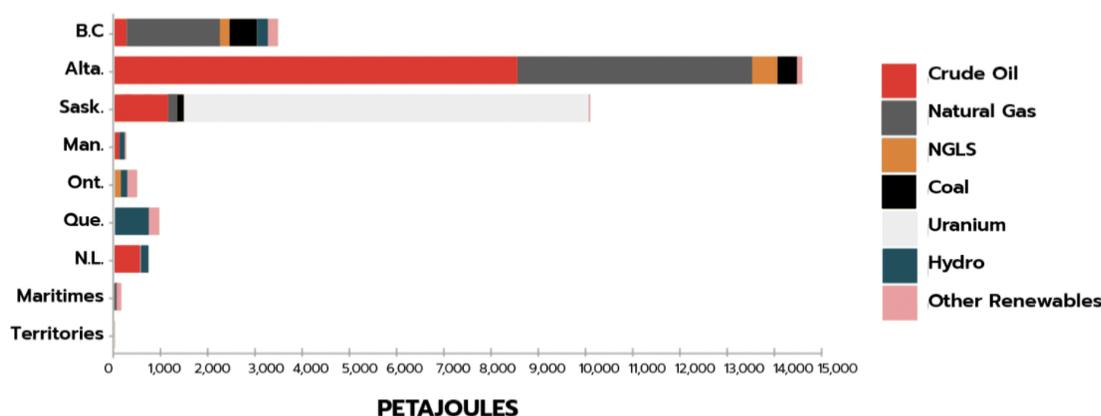
¹⁷³ Ibid.

¹⁷⁴ <https://www.investcanada.ca/industries/cleantech>

Investments and commitments in the development and deployment of semiconductors in clean tech will enable Canada's energy transition¹⁷⁵.

The energy sector created over 832,000 direct and indirect jobs in Canada (2019) and accounts for over 10% of Canada's GDP¹⁷⁶. Globally, Canada is the sixth largest energy producer (China, the U.S., Russia, Saudi Arabia and India round out the top 5). Canada is a top 5 producer of crude oil, natural gas, uranium and hydroelectricity according to Natural Resources Canada.

PRIMARY ENERGY PRODUCTION, INCLUDING URANIUM



SOURCE: Government of Canada. <https://www.nrcan.gc.ca/science-and-data/data-and-analysis/energy-data-and-analysis/energy-facts/energy-and-economy/20062>

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Energy exports in 2019 were \$134.3 billion, or 23% of total Canadian goods exported¹⁷⁸. Meanwhile, "Oil and gas domestic exports totalled over \$122 billion, of which 96% were exported to the U.S."¹⁷⁹

Mining & Minerals

Canada's mineral portfolio has attracted an investment of \$14 billion for construction and machinery¹⁸⁰; with high-level minerals found in every province and territory, Canada has the opportunity to attract a higher return. In 2019 alone, mining in Canada accounted for \$109 billion of our total GDP¹⁸¹ and projected to attract an investment of \$82 billion over the course of 10 years¹⁸². A challenge facing the Canadian mining industry is the ground being lost to Australia in

¹⁷⁵ *ibid.*

¹⁷⁶ <https://www.nrcan.gc.ca/science-and-data/data-and-analysis/energy-data-and-analysis/energy-facts/energy-and-economy/20062>

¹⁷⁷ *ibid.*

¹⁷⁸ *ibid.*

¹⁷⁹ *ibid.*

¹⁸⁰ <https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/minerals-and-the-economy/20529>

¹⁸¹ https://www.nrcan.gc.ca/sites/nrcan/files/mineralsmetals/files/10_key_facts_mineral_sector_2020_ee%20accessibility_low.pdf

¹⁸² <https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/minerals-and-the-economy/20529>



the competition for non-ferrous metal exploration spending. However, taking into account our competitor, Canadian mining assets have seen a 4% increase in 2018¹⁸³.

Semiconductors are the pathway to elevated asset value and a decrease in exploration expenditure. Semiconductors in mining gas sensors have minimized deaths of miners by detecting smoldering and expediting evacuations in the event of a fire. Metal Oxide in Semiconductor Sensors are proven to protect our miners from potential gas leaks, emulating the human nose to detect high threat odours¹⁸⁴. United States mining activities have enabled more than \$3 trillion in U.S. industry sectors, indicative of the value of critical minerals found in semiconductors¹⁸⁵.

Initiatives to Leverage Canada's Mineral Footprint

The Canadian Minerals and Metals Plan (CMMP) introduces six pan-Canadian initiatives to capitalize on opportunities in the minerals industry. In light of COVID pandemic, the federal government is investing \$250 million in innovative, early-stage companies through the Industrial Research Assistance Program, and the provincial and territorial governments also rolled out wage subsidies, work-sharing programs, tax breaks, and other incentives. Federal, provincial and territorial governments are working together to leverage “resources, mining and innovation ecosystems, and global leadership to position Canada as the supplier of choice for global markets”¹⁸⁶. Furthermore, trade partnerships like the Canada–U.S. Joint Action Plan on Critical Minerals Collaboration will help Canada secure access to the critical minerals and boost global competitiveness. To fortify supply chains in semiconductors and its downstream industries such as electric vehicle manufacturing, Canada will require more funding to boost domestic supply of critical metals and minerals¹⁸⁷.

Agriculture

Agriculture and Agri-Food is a key sector that drives the Canadian economy, accounting for 7.4% of GDP and creating one in eight jobs in 2018¹⁸⁸. In 2017, the sector's net cash income reached a record high at \$14 billion, but experienced a drop the following year to \$11 billion.

¹⁸³ <https://www.minescanada.ca/en/content/mining-canada-0>

¹⁸⁴ <https://www.azomining.com/Article.aspx?ArticleID=1463>

¹⁸⁵ <https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf>

¹⁸⁶ <https://www.nrcan.gc.ca/science-and-data/data-and-analysis/energy-data-and-analysis/energy-facts/energy-and-economy/20062>

¹⁸⁷

<https://www.spglobal.com/marketintelligence/en/news-insights/blog/ev-impact-vaccines-to-boost-job-market-coal-supply-constraints>

¹⁸⁸

<https://agriculture.canada.ca/en/canadas-agriculture-sectors/sector-overviews-data-and-reports/overview-canadian-agriculture-and-agri-food-sector-2018>



Primary agriculture employed 268,779 people in Canada in 2018, including 73,341 in Alberta, Saskatchewan, and Manitoba¹⁸⁹, and the sector represents a particularly large share of provincial GDP in Saskatchewan, Prince Edward Island, and Manitoba¹⁹⁰.

Tech-enabled agriculture practices rely heavily on semiconductors; Reuters reports that, in May 2021, farm equipment manufacturer John Deere indicated that the ongoing semiconductor shortage represents “a ‘significant’ risk to its production schedule.” This, in turn, impacts farms of all sizes, the vast majority of which require chip enabled equipment in order to operate.¹⁹¹

Semiconductors are a critical component of autonomous vehicles and industrial robots that are increasingly adopted in agriculture, a serviceable market of approximately \$15 billion. The imaging and robotics technology utilizes autonomous navigation to enable coverage of large or segmented areas. The agricultural sector is a large serviceable market for automobile and industrial technology companies that rely on semiconductors, with high potential for digitization and automation¹⁹².

As the agriculture industry navigates increasing climate uncertainty, it is poised to rely even more on chip enabled technology to continue to grow the food we need. Semiconductor use in agriculture is widespread, and includes GPS receivers, yield data collection equipment, and operational automation. In addition, infrared sensors, stationary agriculture systems and image sensors have proven to bolster agriculture practices. Infrared sensors, for example, are effective in monitoring plant health, and the image sensors work to provide the perspective needed to survey the plant health of entire fields in one system.¹⁹³

Chemicals and Materials

The semiconductor supply chain requires many chemicals as raw inputs and production supplies, some of which are currently experiencing a shortage. Examples of major chemicals include nitride, phosphorus, gallium, germanium, tin, and arsenic¹⁹⁴. In addition, large quantities of freshwater are required during the manufacturing process, which Canada has the third highest supply of in the world (20% of the world's freshwater supply). Canada has a strong chemical industry overall, with federal- and provincial-level policy support¹⁹⁵. Canada's strength

¹⁸⁹ <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210021601>

¹⁹⁰ <https://www150.statcan.gc.ca/n1/daily-quotidien/190730/t001a-eng.htm>

¹⁹¹ <https://www.reuters.com/business/deere-raises-forecast-profit-more-than-doubles-equipment-demand-2021-05-21/>

¹⁹² <https://semiengineering.com/smart-farming-accelerates/>

¹⁹³ <https://www.semiconductorforu.com/sensors-agriculture-technology/>

¹⁹⁴ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6237170/>

¹⁹⁵ https://www.international.gc.ca/investors-investisseurs/assets/pdfs/download/Chemicals_and_Plastics.pdf



in semiconductor chemicals lies in research expertise and capabilities¹⁹⁶, specifically in photolithography, which is the most chemical-intensive step in the semiconductor production process. Assets include the nanoFAB at the University of Alberta¹⁹⁷, Toronto Nanofabrication Centre at the University of Toronto¹⁹⁸, and the GCM Lab in Montreal¹⁹⁹.

Aerospace

Canadian aerospace is a key player in the manufacturing sector, holding the spot for the top research and development stakeholder, with investments totalling to \$1.8 million in 2018 alone. The Canadian aerospace industry has a value chain of over \$20 million in GDP and hosts 160,000 jobs directly and indirectly. The aerospace industry across the globe is upgrading aircrafts to incorporate semiconductor devices that modernize aircraft computers, information systems, and guidance control. Canada has an opportunity to be on the forefront of aerospace technology; the world semiconductor market in the aerospace sector is expected to see a compound annual growth rate (CAGR) of 5% by 2022.

Semiconductors power the competitive advantage of Canadian aerospace companies, like Bombardier, which is leading the industry with a revenue of \$16.2B, and MDA Corporation, a Canadian space company with a global reach. Sensors in aerospace help with data processing units, computers, data display systems, and aircraft guidance control assemblies.

Semiconductors in aerospace increase the power and range of current radar systems. RF energy units, for example, elevates bandwidth performance and supplies higher overall performance in radar range. RF electricity semiconductors reduces the amount of radar systems needed to screen an identical area, which reduces overall expenditure²⁰⁰.

Talent and Skills For the Future of the Semiconductor Industry

Despite established research funding, increasing enrollment in postsecondary STEM programs, the global demand for semiconductors, and Canada's historical reputation in the semiconductor industry, many Canadian engineering school graduates focus on other fields, or work in the U.S. and other countries.

¹⁹⁶

<https://uwaterloo.ca/research/waterloo-commercialization-office-watco/business-opportunities-industry/monomeric-oligomeric-and-olymetric-semiconductors-containing>

¹⁹⁷ <https://www.nanofab.ualberta.ca/capabilities/lithography/>

¹⁹⁸ <https://tnfc.utoronto.ca/tnfc/capabilities/photolithography/>

¹⁹⁹ http://www.gcmlab.ca/microfabrication/photolithographie_v3/?lang=en

²⁰⁰ <https://medium.com/technology-innovations-insights/semiconductor-trends-in-aerospace-industry-92e5f96d081d>



This situation exists because there is no national talent pipeline that provides the skills training, support, and industry connections necessary to work in the semiconductor industry in Canada. The resulting dearth of opportunities limits the growth potential of Canada's semiconductor industry.

Canadian graduates from schools of engineering are lured away from working in Canada due to favourable conditions in other countries — particularly the U.S.

“Canada has incredible talent, but they aren't staying here. A lot of people look across the border. The salaries are higher and the weather is better, and they end up leaving.”
- Taj Manku (Founder and CEO, Cognitive Systems Corp)

Canada's Strengths

Reputation of Postsecondary Programs

Universities and colleges in Canada are sought-after destinations for international engineering students. International enrollment in postsecondary engineering and engineering technology programs increased by 156% between the 2010-11 and 2018-19 academic years, rising from just under 20,000 to over 50,000 students in that time²⁰¹.

Canadian institutions rank among the world leaders in engineering education; the 2021 global ranking by international higher education analytics firm Quacquarelli Symonds places four Canadian schools of engineering in the top 50 — more than any country besides the U.S., U.K., and China:

- 18. University of Toronto
- 32. University of British Columbia
- 38. University of Waterloo
- 40. McGill University²⁰²

In addition, Canadian postsecondary institutions have a historical reputation as incubators of electronics innovation. For example, ATI Technologies, Inc. was founded in 1985 by University of Toronto engineering alumni — including longtime ATI President Lee Ka Lau, and members of the Microelectronics Development Centre (an organization established at U of T's engineering school). ATI grew to become a global leader of chipsets for computer graphics hardware, and was acquired by AMD for \$5.6 billion in 2006. The former ATI campus in Markham now operates

²⁰¹ <https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3710016301>

²⁰² <https://www.topuniversities.com/university-rankings/university-subject-rankings/2021/engineering-technology>

under the AMD banner²⁰³.

Interest in Post-secondary Engineering Programs

Overall enrollment in Canadian post-secondary engineering programs has remained consistently strong in recent years.

From 2014-2019, the total cumulative enrollment in electronics-related post-secondary programs in Canada was 2,360,691. In 2019, total enrollment was 550,914, accounting for 23.47% of all Canadian post-secondary enrollments, compared to 21.57% in 2014. Of the three fields of study identified below, Architecture, engineering and related technologies had the highest proportion in 2019 (10.83%). From 2014 to 2019, Mathematics, computer and information sciences programs saw the highest percentage of increase (50.66%)²⁰⁴.

Undergraduate student enrolment in accredited engineering programs totalled 88,273 in 2019. This is an increase of 7.0 per cent from 2015 and a 1.0 per cent decrease from 2018²⁰⁵.

Electronics Related Research Funding

Canadian universities and colleges have an established source of research funding for electronics-related research and development.

From 2015-2020, the Natural Sciences and Engineering Research Council of Canada awarded \$536.08 million²⁰⁶ to academic institutions for electronics-related research, including Semiconductor, Integrated circuits, Microelectronics, etc.²⁰⁷, which accounted for 8.06% of all funding awarded to Canadian universities and colleges across all research subjects over this period (\$6.65 billion). The top Canadian universities and colleges have also dedicated additional research funding to electronics-related fields, from sources including other federal grants, provincial government grants, private sponsorships, foreign funding, etc.

The existence of this funding pool represents a foundation for semiconductor research and development in Canadian postsecondary institutions, upon which a more robust and diverse support structure can be built — one that enables Canadian-trained engineers to innovate locally, and bring those innovations to market.

²⁰³ <https://alumni.engineering.utoronto.ca/alumni-bios/lee-lau/>

²⁰⁴ <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3710001101>

²⁰⁵ <https://engineerscanada.ca/reports/canadian-engineers-for-tomorrow-2019>

²⁰⁶ https://www.nserc-crsng.gc.ca/ase-oro/index_eng.asp

²⁰⁷ Research Subjects Included: Artificial intelligence, Semiconductors, Circuit theory, Communications networks, Communications systems, Electrical and electronic engineering, Electronic materials and components, Industrial and power electronics, Integrated circuits, Microelectronics, Microwave and millimeterwave devices, circuits and technologies, Semiconductor fabrication and packaging, Wireless communication systems, Computer architecture and design, Computer hardware, Information technology, Mechanical engineering, Photonics



Top 10 Canadian Universities for Electronics-Related R&D

University	NSERC Funding Millions (2015-2020)
University of Waterloo	\$87.99
University of Toronto	\$53.89
Université de Montréal	\$34.50
University of British Columbia	\$29.19
École Polytechnique de Montréal	\$27.61
McMaster University	\$22.78
Université de Sherbrooke	\$22.45
University of Alberta	\$21.21
McGill University	\$18.62
Carleton University	\$16.21

Source: NSERC

https://www.nserc-crsng.gc.ca/ase-oro/index_eng.asp

Top 20 Canadian Colleges for Electronics-Related R&D

College/CEGEP	NSERC Funding Millions (2015-2020)
Cégep de Trois-Rivières	\$2.52
Cégep de Saint-Jérôme	\$2.40
George Brown College of Applied Arts and Technology	\$2.16
Centennial College	\$1.93
Nova Scotia Community College	\$1.79
Northern Alberta Institute of Technology	\$1.51
Red River College of Applied Arts, Science and Technology	\$1.47
Lambton College of Applied Arts and Technology	\$1.33
Cégep de Sept-Îles	\$1.20
Durham College	\$1.11
New Brunswick Community College	\$0.77
Cégep Edouard-Montpetit	\$0.58
Mohawk College of Applied Arts and Technology	\$0.51
Southern Alberta Institute of Technology	\$0.45
Sheridan Institute of Technology and Advanced Learning	\$0.45
Cégep de Sainte-Foy	\$0.45
C.E.G.E.P. Lévis-Lauzon	\$0.41
Algonquin College of Applied Arts and Technology	\$0.40
Cégep André-Laurendeau	\$0.31
Seneca College of Applied Arts and Technology	\$0.29

Source: NSERC

https://www.nserc-crsng.gc.ca/ase-oro/index_eng.asp



Top 10 Universities for Electronics-Related Doctorates & Research Chairs

University	Doctorate Enrollment (2020)	Canada Research Chairs
University of Toronto	761	9
University of Waterloo	758	5
Carleton University	No information	5
University of British Columbia	755	4
Université de Sherbrooke	No information	4
Université Laval	No information	4
École de technologie supérieure	No information	3
McGill University	679	2
University of Ottawa	386	2
University of Calgary	No information	2

Source: Government of Canada
<https://www.chairs-chaire.gc.ca/chairholders-titulaires/index-eng.aspx>
 UBC: <https://www.grad.ubc.ca/about-us/graduate-education-analysis-research/enrolment-demographics>
 UofT: <https://www.sgs.utoronto.ca/about/explore-our-data/phd-degree-completion/f>
 UWaterloo: <https://uwaterloo.ca/institutional-analysis-planning/university-data-and-statistics/studentdata/student-headcounts>
 McGill: <https://www.mcgill.ca/es/registration-statistics>
 UOttawa: <https://www.uottawa.ca/institutional-research-planning/resources/facts-figures/fact-book/enrolment>

Doctoral Enrollments & Canada Research Chairs

Canada has a total of 47 research chairs in Electrical & Electronic Engineering and Electrical & Computer Engineering, accounting for 2.6% of all Canada Research Chairs (1,843)²⁰⁸. Every year, top Canadian universities award hundreds of doctoral degrees to candidates in Electrical Engineering, Computer Science and Engineering, etc.^{209,210}

Case Study: Fostering Talent and Skills to Drive Innovation at Seneca College

Combining the highest academic standards with practical, hands-on learning, expert teaching faculty and the latest technology ensures Seneca graduates are career-ready. Seneca offers degrees, diplomas, and certificates renowned for their quality and respected by employers. Additionally, to meet industry demands, Seneca offers career- and profession-based microcredential programs to equip students and employees with in-demand skills and knowledge in key industries and sectors. Microcredentials offer flexibility, cost-effectiveness, and expediency in providing in-demand knowledge.

²⁰⁸ <https://www.chairs-chaire.gc.ca/chairholders-titulaires/index-eng.aspx>

²⁰⁹ Doctorate Fields of Study Included: Electrical Eng, Math, Computer Science & Eng, Mechanical & Mechatronics Eng, Physics

²¹⁰ Canada Research Chairs Disciplines Included: Electrical and Electronic Engineering, Electrical and Computer Engineering



ventureLAB's Hardware Catalyst Initiative and the School of Electronics & Mechanical Engineering Technology (SEMET) at Seneca are collaborating on opportunities in the hardware and semiconductor industry to foster a stronger talent pipeline and build a curriculum that is responsive to industry needs. SEMET capstone projects have been developed to offer students real-world integrated learning experiences, a chance to develop innovative solutions, have use of state-of-the-art lab equipment through ventureLAB's Hardware Lab, build valuable industry connections and access jobs upon graduation.

Since 2012, the Open Source Technology for Emerging Platforms (OSTEP) applied research program at Seneca has partnered with over 20 Canadian companies on various projects. Super-Embedded systems is emerging as a high-demand research area for the program with significant industry traction. Seneca's OSTEP program complements existing Hardware Catalyst Initiative capabilities especially in aspects related to software development, optimization and integration.

Canada's Gaps and the Future of Work

Domestic Student "Brain Drain"

Like other STEM disciplines, Canadian electrical engineering school graduates are lured away from work in Canada. One quarter of STEM graduates surveyed in a 2018 study by researchers from Brock University and the University of Toronto left Canada to work. More than 80% found work in the U.S., citing higher pay, the size and reputation of American firms, and a broad scope of work as their top reasons for leaving home²¹¹.

In Canada, the average salary for workers in Semiconductor and Other Electronic Component Manufacturing was CAD 47,320 in 2019, slightly under the average for all manufacturing workers at CAD 59,973. Employees in Architectural, Engineering and Related Services (including non-semiconductor-related engineering) earned on average \$92,952.

In the U.S., salary ranges for different roles in the semiconductor industry are shown in the chart below. The average salary was USD \$170,000 (~CAD \$213,480) in 2019, well above the national average \$53,490. Employees in Production earned on average USD 94,924 (~CAD 120,000), while those in Architecture and Engineering are amongst the highest earners in the industry at USD 226,145 (~CAD 283,880) annually.²¹²

²¹¹ <https://brocku.ca/social-sciences/political-science/wp-content/uploads/sites/153/Reversing-the-Brain-Drain.pdf>

²¹² https://www.semiconductors.org/wp-content/uploads/2021/05/SIA-Impact_May2021-FINAL-May-19-2021_2.pdf



Declining Interest in Core Engineering Programs

Despite relatively high overall enrollment, the number of Canadian students in electrical engineering has decreased overall since 2015²¹³. (This is offset somewhat by a rise in computer engineering, but is nevertheless concerning for the stability of the semiconductor talent pool.)

Many students are choosing mechatronics and other interdisciplinary programs over pure engineering streams, limiting the capacity of institutions to provide fundamental knowledge in core engineering and mathematical principles required for ongoing semiconductor innovation.

Semiconductor Growth Opportunities and Skills in Demand

Other than a degree in Computer Engineering, Electrical Engineering, Mechanical Engineering, Physics or a related field, semiconductor engineering jobs often require knowledge and experience in semiconductor design, simulation, validation, analysis, and engineering documentation. Many employers also require programming (Python, C++, C, etc.) and IT systems (SAP, Tableau, Power BI, etc.) training. Other nice-to-have skills include data analysis, project management, and written and verbal communication. Depending on the position, industry-specific certifications and experience may be required.

Semiconductor companies in Canada are also seeking workers who can demonstrate an understanding of quantum mechanics in addition to electrical engineering skills. In addition, these skills have the potential to enable Canadian engineering school graduates to succeed as entrepreneurs in the semiconductor sector — particularly in the realm of quantum computing, which is poised for exponential growth.

Like jobs in other sub-sectors of the semiconductor industry, quantum-related roles also require a degree in Engineering or Physics, that varies from an Associate's to PhD depending on the role. Most roles place a heavier emphasis on research, modelling, and technical documentation and presentation skills. Deep knowledge of semiconductor fabrication and characterization techniques, as well as proficiency in programming languages and other computer tools are often required. Experience in physics, electronics, and materials science, or in academic or industrial laboratory and fabrication facilities is highly desirable.

By SIA's characterization, quantum-related semiconductor roles would fall into the "Computer and Mathematical," "Architecture and Engineering," and "Life, Physical, and Social Science" categories, which all have average salaries above USD 200,000 (~CAD 250,000). In Canada, these roles would be in the "Professional, Scientific and Technical Services" category by NAICS

²¹³ <https://engineerscanada.ca/reports/canadian-engineers-for-tomorrow-2019>



characterization, which had an average salary of CAD 78,845 in 2019 across all sectors (including outside of semiconductors). Those employed in these highly technical and professional roles tend to see higher salaries than the average worker in the semiconductor industry.

Due to the specialized and technical nature of quantum roles, there are fewer openings compared to general semiconductor engineering positions, and tend to be in large corporations with high R&D capabilities or in research institutions/labs. Furthermore, a large portion of employment in the semiconductors industry overall is in production, sales, business development. Quantum-related semiconductor openings concentrate in research specialist, scientist, and engineer positions, typically in the middle management level.

Disconnect Between Postsecondary Institutions and Industry

Across all sectors, in Canada and around the world, industry is calling out for workers with a broad skillset of future-ready attributes. According to the World Economic Forum's *Future of Jobs Report 2020*, the top five in-demand skills for Canadian companies are:

1. Analytical thinking and innovation
2. Active learning and learning strategies
3. Technology design and programming
4. Critical thinking and analysis
5. Complex problem-solving²¹⁴

These skills are best developed in authentic learning environments. Although co-op programs and other work integrated learning opportunities exist at some institutions (like the University of Waterloo's co-op program, which sees engineering students complete their bachelor's degrees with as many as 24 months of industry experience), the small number of companies producing semiconductors in Canada and the lack of dedicated resources for work integrated learning limits the capacity of industry and institutions to provide sufficient opportunities for engineering students poised to gain experience in the semiconductor industry.

As a result, there is a dearth of opportunities for Canadian engineering students to engage directly with the semiconductor industry in order to authentically develop the skills and attributes they will need to be successful.

Furthermore, a misalignment persists between academic research and long-term commercial and industrial applications within the semiconductor industry. Stakeholders have signalled that these gaps in support for commercialization of academic research limit the industry's ability to

²¹⁴ <https://www.weforum.org/reports/the-future-of-jobs-report-2020>



fully leverage Canada's research in key areas like AI, quantum, material and chemical production, and manufacturing processes.

“You need a place where you can make commercial grade production runs and they don't exist in college, or to a large extent in the university world either. If you want to do a trial run to get it right, you need a Foundry that can do it. And that's where, when you're talking about grants, I would set up a national, industrial hub where a company could pay to have a certain number of runs done and then go back.”

- Darren Lawless (Assistant Vice-President of Research, Innovation and Partnerships, McMaster University)

The result is that institutions and semiconductor companies continue to primarily operate in silos, collaborating on an ad-hoc basis when conditions permit and sometimes encountering conflicting priorities.

“There's a conflation of two priorities for university-industry collaboration: the training and incremental research; and long-term knowledge creation. Neither party seems willing to admit that these priorities can be incongruous. When these priorities do come into conflict, we get legal problems, IP or export control, or mismatch of timelines and outcomes.”

- Anthony Chan Carusone (Professor of Electrical Engineering, University of Toronto)

Lack of Entrepreneurship Skills Training, Commercialization Support, and Opportunities

Despite the existence of entrepreneurship education in some engineering programs, there remains a lack of cross-pollination of entrepreneurial and engineering knowledge and skills. This is necessary in order to create and nurture conditions to stimulate the creation of more made-in-Canada semiconductor success stories, like ATI Technologies.

Incubator programs and related entrepreneurial support ventures inside postsecondary institutions tend to be focused on bringing to market goods and services that rely on semiconductors, in lieu of stimulating the development of the chips themselves. Semiconductor development takes time, patience, and significant investment, whereas software development can more easily be absorbed within the relatively short cycle of a typical incubator program, and tends to scale toward profitability at a more rapid pace. These conditions result in a lack of funding and opportunities for hardware-related entrepreneurship skill development within postsecondary institutions.



In addition, Canada lacks a cohesive strategy for managing technology transfer inside of higher education. In short, prospective entrepreneurs developing semiconductor technologies are not receiving the support and instruction they need to protect their IP, which further inhibits the growth of the industry.

Diversity, Equity and Inclusion Trends in Computer, Electrical and Electronics Related Fields

Strengthening Canada's electronics industry and manufacturing supply chain resiliency requires not only investing in and retaining talent, but also leveraging and encouraging the development of diverse talent. In its 2019-2021 Strategic Plan, Engineers Canada has identified "promot[ing] diversity and inclusion as its highest non-regulatory priority", specifically to "increase the number of women and Indigenous people entering, thriving, and remaining in the profession"²¹⁵.

As of 2017, only 13% of practicing engineers were women and 3% were Indigenous. In 2020, women held 21% of jobs in durables-manufacturing and 43% of jobs in professional, scientific and technical services²¹⁶. Engaging early talent and promoting equity and inclusion in the schooling system is crucial for increasing the diversity of the workforce. In 2019, women made up 28% of students in post-secondary education in mathematics, computer and information sciences and 22% in professional, scientific and technical services. The fractions have increased 2-3% from 2014 to 2019 as more programs, scholarships, and publicity attempted to encourage women to enter the STEM fields²¹⁷. However, greater commitment is required to reach Engineers Canada's 30 by 30 goal (raising the percentage of newly licensed engineers who are women to 30% by 2030), both in training and retaining talent²¹⁸. Whereas 26 (60%) out of 47 NSERC research chairs in Electrical & Electronic Engineering and Electrical & Computer Engineering are members of visible minority groups, only 9 (20%) are women²¹⁹. Building a talent pipeline for women and other historically underrepresented groups in engineering, electronics, and manufacturing will be critical to changing the face of the industry.

**"Canada produces some of the top STEM talent around the globe, yet continues to lack diversity in Canada's semiconductor industry. The pillars of diversity, equity, and inclusion must be embedded into Canadian post-secondary institutions to ensure the long-term diversification of talent in STEM."
- Rhonda Lenton, President, York University**

²¹⁵ <https://engineerscanada.ca/sites/default/files/board/engineers-canada-strategic-plan-2019-2021.pdf>

²¹⁶ <https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1410002301>

²¹⁷ <https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3710001101>

²¹⁸ <https://engineerscanada.ca/diversity/women-in-engineering>

²¹⁹ <https://www.chairs-chaires.gc.ca/chairholders-titulaires/index-eng.aspx>



Investment Capital: Canada's Strengths

Growing Venture Capital (VC) investments in the ICT sector

The overall VC landscape has seen a pickup in activity in the first half of 2021, with a record-breaking \$8.3B invested. There has been a general upward trend in Canadian VC funding towards the Information, Communications & Technology (ICT)²²⁰ sector since 2017, which includes semiconductor companies. Particularly, in the first half of 2021, the sector received 64% of the total VC investment, with \$5.3 billion invested across 232 deals, already surpassing 2020's total of \$2.5 billion by 114%. The amount of each deal has also increased significantly to \$22.8 million²²¹. However, it is important to note that there was also a record-high level of foreign VCs investing in Canadian companies, including those in the U.S., U.K., Switzerland, Germany, Singapore and Australia.

Strong public investment in academic research

Since 1991, the Canadian government has awarded \$536 million to academic institutions through NSERC for semiconductor or electronics-related research. Over the same period, Canadian universities have developed research expertise in cutting edge technologies. The number of students enrolled in STEM-related post-secondary programs and the number of NSERC research chairs continue to increase every year.

Investment Capital: Canada's Gaps

Public R&D investment in industry significantly lower than academia

Over the past 20 years, the Canadian government has awarded a total of \$7.9 million in R&D funding to semiconductor or electronics companies, only 1.5% of that awarded to academic institutions. On a global level, Canada's total R&D expenditure as a percentage of GDP and government R&D budget also fall behind other countries. As the semiconductor industry has one of the highest capital intensity levels, companies, particularly early and growth-stage ones, would significantly benefit from access to public grants and incentives.

²²⁰ ICT includes computer hardware and software and services, internet software or services, ecommerce, electronic & semiconductor, mobile and telecom technologies and services.

²²¹ <https://www.cvca.ca/research-insight/market-reports/h1-2021-vc-pe-canadian-market-overview/>



Lagging Private Equity (PE) funding in the ICT sector

Compared to the VCs' interest in the ICT sector, PE investments in the first half of 2021 lagged behind at \$1.2 billion across 85 deals, with the average investment size being \$14.1 million. Given that it takes more capital to put the chip to volume production than to design it, companies face the challenge of lacking later-stage capital for further scaling and innovation²²².

Decline of domestic M&A opportunities

In the 1990s to 2010s, Canada's semiconductor industry was bustling with innovations and mergers and acquisitions, a popular path for mature startups. The buyer was often a larger international corporation with a strong presence in Canada, and sometimes a larger domestic establishment.

Investment Capital: Incentives and Policies (Global vs. Canada)

Canada makes investments in R&D (particularly academic institutions and industry networks), provides tax credits through the SR&ED program, and enjoys beneficial trade relationships with other countries. With an openness to business and innovation-driven economy, Canada can leverage its existing strengths to foster the growth of the semiconductor industry.

However, Canada's commitments fall behind other countries, including its OECD peers, particularly in direct grants and tax incentives for domestic companies and foreign MNEs. Leveraging Canada's current research capabilities and expertise, but more importantly, addressing the gaps in industry-facing funding sources to promote R&D and commercialization of advanced technologies will underline the future of Canada's technology sector.

“Industry can sometimes be shortsighted because they have to get the next product out in the next couple of years and they don't want to invest in long-term research. And, that is where universities need some funding from federal organizations like NSERC, but those funding opportunities are limited.”

- Masum Hossain, Associate Professor, University of Alberta

Furthermore, greater grants and tax incentives aimed not only at R&D but also manufacturing will attract global foundries to establish facilities in Canada, directly strengthening Canada's supply chain and reducing dependence on other countries.

²²² <https://www.cvca.ca/research-insight/market-reports/h1-2021-vc-pe-canadian-market-overview/>



IP: Incentives and Policies (Global vs. Canada)

According to the Canadian Intellectual Property Office (CIPO), the number of patents filed in Canada decreased in 2019 by 3% but retained its position for the second highest for resident filings (12%). At the same time, the United States accounted for almost half (46%) of all applications, while France and China have shown strong growth in applications, underscoring the importance of companies from these countries to access Canadian markets²²³.

Additionally, Canadians continue to have strong filings in international jurisdictions — in 2018, 66% of all Canadian international patent applications were in the US, 8% in the EU, and 6% in China.

Although the federal government has shown strong commitment to business growth and innovation through a new IP strategy, looking at policies and incentives in other jurisdictions can identify potential areas of opportunity for Canada. Leveraging existing Canadian IP assets such as [Explore IP](#), [Innovation Asset Collective](#), and [Patent Collective Pilot Program](#), strategic opportunities exist to further bolster Canadian IP support and growth.

Jurisdiction	Program or Initiative	Incentive or Policy
Canada	National IP Strategy	<p>Inclusion of IP as a Reimbursable Expense — “up to \$1.5 million of eligible expenses by Canadian-controlled private corporations made on or after Budget Day and before 2024”²²⁴</p> <p>Supporting Use of IP in Small Business Financing — proposal to expand “loan class eligibility to include lending against IP and start-up assets and expenses, increasing the maximum loan amount, and extending the loan coverage period”²²⁵</p> <p>Promoting Use of Canadian IP Services — \$90 million, over two years to create ElevateIP, a program to help accelerators</p>

²²³ https://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/h_wr04873.html

²²⁴ https://ipic.ca/_uploads/607f30df4c3ef.pdf

²²⁵ Ibid.



		and incubators provide start-ups with access to expert IP services; \$75 million over three years, starting in 2021-22, for the National Research Council's Industrial Research Assistance Program to provide high-growth client firms with access to expert IP services ²²⁶
	Québec Patent Box	Reduces "the corporate tax rate from 11.5% to 2% on patent royalties and up to 75% of profits from other specified forms of IP-related income, provided that the taxpayer has carried out research and development (R&D) in Québec and that the IP being commercialized results, in whole or in part, from R&D carried out in Québec" ²²⁷
	Saskatchewan Commercial Innovation Incentive (Patent Box)	Offers eligible corporations a lower corporate tax rate of 6% ²²⁸
UK	UK Patent Box	Reduced rate of 10% Corporate Tax if it exploits patented inventions and innovations ²²⁹
Israel	Innovation Box	"Reduced corporate income tax rate of 6% on IP-based income and on capital gains from future sale of IP" ²³⁰
Singapore	IP Development Incentive	"[D]esigned to encourage the use and commercialization of research and development activities by offering concessionary tax rates of either 5% or 10% on qualifying IP income" ²³¹

²²⁶

<https://ipic.ca/news/budget-2021-ip-funding-expansion-of-ip-programs-ipic-to-work-closely-with-government-on-rollout-2021-04-20.htm>

²²⁷ <https://www.iposgoode.ca/2021/07/a-lesson-for-canada-new-report-deems-uks-patent-box-a-failure/>

²²⁸

<https://www.saskatchewan.ca/business/investment-and-economic-development/business-incentives-and-tax-credits/saskatchewan-commercial-innovation-incentive>

²²⁹ <https://www2.deloitte.com/uk/en/pages/tax/solutions/the-uk-patent-box.html>

²³⁰ <https://www.fdiintelligence.com/article/69813>

²³¹ <https://mnetax.com/singapore-adopts-beps-compliant-ip-tax-incentives-43117>



	Singapore IP Strategy (SIPS) 2030	A 10-year plan committed to strengthening “Singapore's position as a global hub for intangible assets (IA) and IP, and to maintain Singapore's top rank as an IP regime” ²³²
EU	National Patent Box (Spain)	Partial exemption for income from certain intangible assets — 15% reduced tax rate ²³³
	Innovation Box (Netherlands)	Offers an effective 80% tax advantage on profit derived from innovation. Qualifying innovative profits are effectively taxed against 5% instead of the regular 25% corporate income tax ²³⁴
	Patent Box (France)	Reduced rate for long term capital gains and profits from the licensing of IP rights from 33% to 10% ²³⁵
Switzerland	Licence Box	Introduced in 2020, the Swiss patent box “enables companies to lower their tax base if they own patents or comparable rights (licenses) and incur R&D expenses in Switzerland” ²³⁶

²³² <https://sbr.com.sg/information-technology/news/government-unveils-singapore-ip-strategy-2030>

²³³ <https://taxfoundation.org/patent-box-regimes-in-europe-2020/>

²³⁴ <https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/tax/deloitte-nl-tax-dutch-innovationbox-factsheet.pdf>

²³⁵ <https://hmc-ip.com/patent-box-provisions-in-france-the-essentials/>

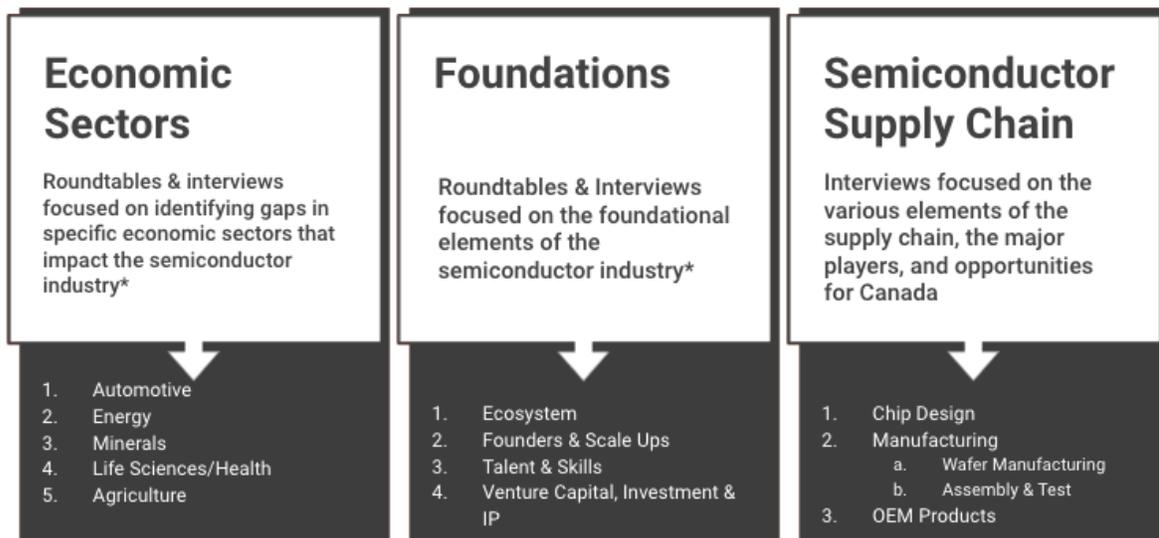
²³⁶

<https://home.kpmg/us/en/home/insights/2020/10/tnf-switzerland-transfer-pricing-opportunities-flowing-from-tax-reform-incentive-regimes.html>

Appendix B: Stakeholder Engagement

ventureLAB, as the ecosystem partner of the Council, led the stakeholder engagement over the Summer of 2021, to ensure the report was driven by primary data-driven insights and industry perspectives to formulate our recommendations to take forward. Over 250 stakeholders were contacted between June and September 2021 for their input, more than twofold the initial list of 100 stakeholders identified in early May 2021. Of these stakeholders who were contacted, over 100 were engaged via three forms of engagement: 1:1 Interviews, Roundtables, and Surveys. Interviews or roundtables were conducted with 80+ stakeholders, while 20+ stakeholders participated via a survey. Several stakeholders who were contacted chose not to participate, referred to another stakeholder, were unavailable, or did not reply.

Ensuring we spoke to stakeholder leaders across the entire continuum in industry and supply chain, innovation, and global trade helped the Council understand the gaps and opportunities, where successful existing initiatives should garner further investment and where gaps present new opportunities to create national strategic advantage as it relates to both talent, skills and jobs and investment capital.



*Some foundational roundtables will include economic sectors (e.g. talent, VC, IP, minerals, etc.) and so are not in the "Economic Sectors" list of roundtables

Graphic: 'Stakeholder Engagement Process'. The graphic above illustrates the breakdown of stakeholders who were engaged throughout the process. Stakeholders were selected based on three areas that are foundational to the semiconductor industry: economic sectors, foundational elements & the semiconductor supply chain.

Stakeholder Engagement Process and Structure

Questions posed to stakeholders during interviews and roundtables were related to the semiconductor supply chain, talent and skills, investment, IP, as well as their area of expertise/focus.

Interviews and roundtables were recorded and transcribed, with express approval by each stakeholder during each interview. All responses were reviewed and aggregated into the final report; specific attribution to individuals has only been included with express prior approval by the stakeholder. The interviews were entirely voluntary, and stakeholders were able to withdraw at any point, pass on any question, or cancel after the fact.

1:1 Interviews

As illustrated in the Stakeholder Engagement Process graphic, stakeholders from across Canada (and internationally) were selected as participants of 1:1 interviews based on their area of expertise, position, and impact within the industry or area of focus. 1:1 or small group interviews were conducted. These 1:1 interviews were the primary source of stakeholder engagement due to the high degree of specialization and expertise of those engaged, as well as to preserve the sensitivity of the information collected and the privacy of individuals.

Questions posted to stakeholders during interviews were related to the semiconductor supply chain, talent & skills, investment, IP, as well as their area of expertise/focus to understand gaps, opportunities for Canada both domestically and globally where Canada can be competitive, comparative and sustainable advantage.

Interviews were recorded and transcribed, with express approval by each stakeholder during each interview. All responses were reviewed and aggregated into the final report; specific attribution to individuals has only been included with express prior approval by the stakeholder. The interviews were entirely voluntary, and stakeholders were able to withdraw at any point, pass on any question, or cancel after the fact.

Roundtables

Roundtables were held as part of the stakeholder engagement process.

- Talent & Skills (Academic Institutions)
- Startup & Scale Up Founders (with a hardware and/or semiconductor focus)
- Venture Capital / Investment (investors within Canada's venture capital landscape)



The Talent & Skills roundtable was hosted in collaboration and generous support from Seneca College. Academic institutions across Canada were invited to participate in the discussion related to the state of the programming, talent and industry connections within the fields of engineering, hardware, and mechatronics.

The Startup & Scale Up roundtables invited founders from leading semiconductor, hardware, and economically related sectors to participate in a discussion regarding the state of the ecosystem, supports, and infrastructure for startups in Canada.

The Venture Capital & Investment roundtable involved discussions with investors who work with companies across the supply chain and at different stages of growth throughout Canada.

Survey Respondents

A survey was created to invite feedback and insights from individuals, associations, and key players across the country.



Appendix C: About the Council

Canada's Semiconductor Council is an independent, industry-led national coalition led by globally recognized Canadian founders, business leaders, chip manufacturers, and investors. The mandate of this Council is to lead a National Semiconductor Strategy and Action Plan that positions Canada to be a global developer, manufacturer and supplier of semiconductor products that are embedded in electric vehicles, medical devices, consumer electronics, and precision agriculture.

Sarah Prevette, Chair; Angel Investor, CEO Future Design School, Founder of BetaKit Named by Inc Magazine as one of the top entrepreneurs in North America, and an active technology investor and renowned thought leader in human centred design, Sarah Prevette is the Founder and CEO of Future Design School, which works with academic institutions around the world to cultivate critical competencies that align with growing industries.

Melissa Chee, Vice-Chair; President & CEO, ventureLAB
Melissa Chee has over 20 years in tech as a past executive at a Canadian semiconductor scale-up and global multinationals. She is the President and CEO of ventureLAB, a leading tech hub which launched the Hardware Catalyst Initiative, Canada's first and only state-of-the-art lab and incubator exclusively for Canadian founders developing transformational semiconductor and related hardware technologies and products.

Kevin O'Neil, Corporate Vice President and Managing Director, AMD Canada
With more than 20 years in the practice of law, Kevin O'Neil is the Managing Director of AMD Canada, which has more than 2,300 employees designing and developing leading-edge semiconductors in Canada. Kevin is responsible for AMD's global intellectual property and AMD Canada's government and university relationships.

Salim Teja, Partner, Radical Ventures
Salim Teja is a Partner with Radical Ventures, an early-stage venture capital firm investing in entrepreneurs applying artificial intelligence to transform massive industries. Salim brings 25 years of experience in the technology sector as an entrepreneur, venture investor, corporate innovator and innovation ecosystem builder.



Appendix D: Acknowledgements

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- Mike McLean (CEO, Innovation Asset Collective)
- Namir Anani (President & CEO, Information and Communications Technology Council)



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- Ron Kelly (CEO, Ambature, Inc.)
- Ron Glibbery (Founder & CEO, Peraso)
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- Sarim Zia (Associate, BDC Capital)
- Scott MacKenzie (Senior National Manager of External Affairs, Toyota)
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- Taj Manku (Founder & CEO, Cognitive Systems Corp)
- Tammy Kim-Newman (University of Waterloo)
- Todd Deaville (Director, Engineering, Magna)
- Tony Pialis (Founder & CEO, Alphawave)
- Vince Jesaitis (Director, Government Affairs, Arm)
- Vincent Gaudet (Professor, University of Waterloo)
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