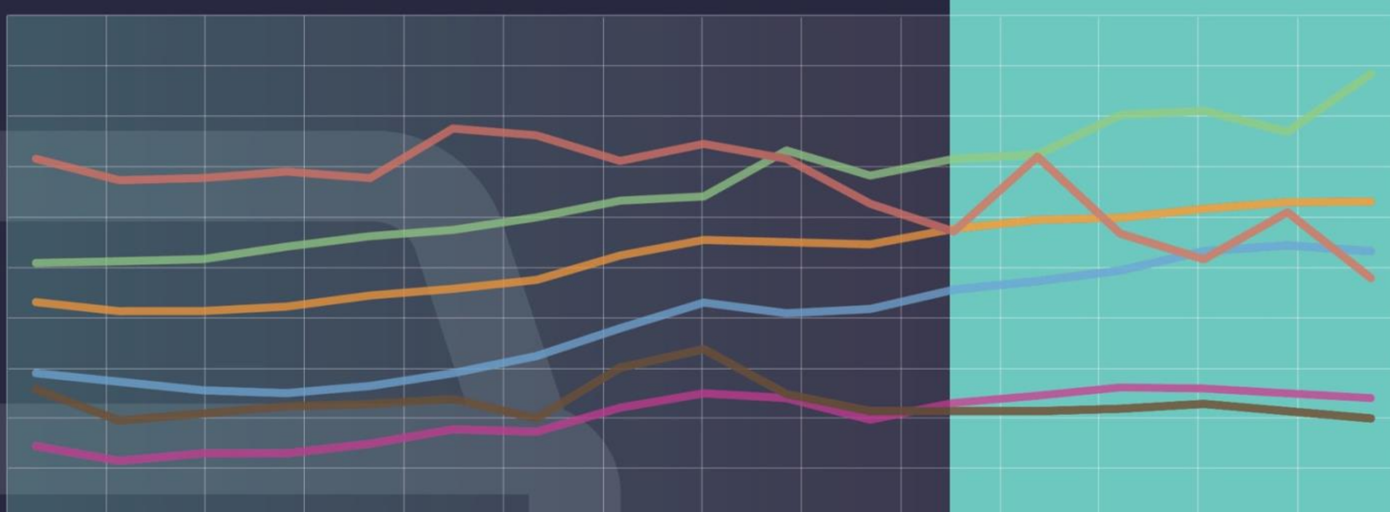
FOCAL Initiative
Future of Canadian Automotive Labourforce
Sur l'avenir de la main-d'œuvre de l'industrie automobile canadienne

TREND REPORT

AUTOMOTIVE INDUSTRY LABOUR MARKET ANALYSIS

CANADA'S AUTOMOTIVE TECHNOLOGY CLUSTERS: LABOUR MARKET CHARACTERISTICS AND REGIONAL SPECIALIZATIONS



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THIS PAPER was prepared for the Auto Labour Market Information (LMI) Project, now known as the Future of *Canadian Automotive Labourforce (FOCAL) Initiative.*

The goal of the project is to help stakeholders better understand the automotive labour market. The Project will create industry-validated, regional, occupational supply and demand analyses and forecasts and skill profiles for skilled trades and other key skilled occupations in the broader automotive sector including vehicle assemblers, parts manufacturers and technology companies that supply the industry. The project will also examine various labour market trends in the sector and facilitate discussions among stakeholders about how to address any forecasted skills shortages and other labour market challenges. The planned outcome of the project is enhanced regional labour market information that will support colleges, employers, policy makers and other stakeholders in taking practical steps to address skills shortages and other labour market challenges in the automotive sector.

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INTRODUCTION

In this series of reports, we observe the contributions of Canada's six automotive technology clusters located in Vancouver, the Greater Toronto and Hamilton Area (GTHA), Kitchener-Waterloo-Cambridge (KWC), Windsor, Ottawa and the Greater Montreal Area (GMA). In doing so, we shed light on each regional cluster's domains of technological expertise, its employment and skills distribution, and the factors that sustain its development. Moreover, we examine the pivotal role played by Canada's automotive technology clusters in the advancement of the country's broader automotive sector through their contributions to its manufacturing capability, development of new product technologies and enhancements to product quality.

Earlier labour market forecasts produced by the Future of Canadian Automotive Labourforce (FOCAL) Initiative determined the number of employees in the broader automotive manufacturing sector.[1] This series of reports examines the labour market characteristics of Canada’s automotive technology clusters. For each cluster, an establishment-level approach is adopted to determine the total number of employees and associated individuals in emerging automotive technology organizations. Those organizations include automotive technology manufacturing facilities, emerging technology development companies, academic labs, organizations, partnerships and government offices. The rationale for broadening our analysis to include those organizations is as follows. First, as we detail in our studies, emerging automotive technology organizations contribute a significant number of jobs to the broader Canadian automotive industry. Second, emerging technology-oriented organizations provide vital research & development (R&D) capabilities to Canada’s automotive manufacturing and automotive technology sectors. Third, those organizations have also supported the formation of numerous emerging technology company start-ups and spin-offs with expertise in connected, autonomous, shared and electrified (CASE) vehicle technologies.

This report's primary purpose is to provide background information on the main domains of technological innovation in the automotive industry and our methodology for classifying each of Canada's automotive technology clusters. It begins by defining economic clusters and examining how they are traditionally formed. Next, it outlines the primary technology domains that were used to identify emerging automotive technology organizations in Canada. After

[1] Labour Market Forecast Reports (2020), Future of Canadian Automotive Labourforce (FOCAL) Initiative

that, this report details our methodology for classifying Canada's automotive technology clusters.

In addition to this report, six individual studies follow that are dedicated to examining each of Canada's automotive technology clusters. Those studies recount the factors that contributed to each cluster's formation. They also provide the number of organizations that operate in each cluster, the number of employees and individuals and their occupational distribution. The studies conclude with a brief discussion highlighting the structure and the key companies in each region.

DEFINING ECONOMIC CLUSTERS

Economic clusters are geographical agglomerations of interlinked firms, specialized suppliers, associational organizations, and specialized labour pools (Porter, 2000). Clusters often form around one dominant industry or domain of technological expertise, such as automotive manufacturing. Moreover, they typically take root in sub-national locales, such as city regions or provinces (Wolfe and Gertler, 2004).

Since the early 2000s, clusters have attracted increased interest from economic development professionals and policymakers (see OECD, 2001, 2010). That interest has been spurred by the numerous purported benefits that clusters provide in the form of local, regional and national-level-development. Indeed, considerable evidence indicates that firms operating in economic clusters are more innovative and partake in greater levels of R&D (see Porter, 2001; Cooke, 2009). Beyond that, clustered firms and industries are observed to provide significantly more employment than their non-clustered equivalents (Spencer, Vinodrai, Gertler & Wolfe, 2010). Clusters are also identified to be essential generators and attractors for skilled and talented labour (e.g., STEM graduates and other highly qualified personnel) (Martin, Florida, Pogue and Mellander, 2015).

While there is consensus on how to define economic clusters and the benefits they pose for economic development, there is considerable disagreement over how individual clusters take form. With that being said, several studies do emphasize the importance of particular agents and local characteristics in cluster formation. Research indicates that the presence of anchor firms (e.g., a domestic automotive OEM) in a regional economy can assist in the formation of industry clusters (Porter, 2000; Molot and Mytelka, 2009). Similarly, research has shown that clusters may form as a by-product of entrepreneurial and enterprising individuals' actions in some locales (Feldman and Francis, 2006). There is also some evidence that local labour markets defined by in-demand skills and occupations may attract clustered development (Gertler, Florida, Gates and Vinodrai, 2002). Finally, several studies indicate that public policies may "seed" clustered forms of development through measures that enhance local labour markets, R&D capacity, commercialization activities and company integration with universities and colleges (Bekar and Lipsey, 2004; Wolfe, 2009).

MAJOR AUTOMOTIVE TECHNOLOGIES AND TRENDS

To identify Canada's automotive technology clusters, we first selected a list of major automotive technologies that stand behind the industry's advancement. In doing so, we referred to the CAR Group's Technology Roadmap, which details future trends for the automotive industry. In its report, CAR identified three technological streams shaping the automotive industry: vehicle technologies (e.g., powertrain, ICEs, energy storage, materials and intelligent mobility), production technologies (i.e., manufacturing and production systems) and mobility (CAR/ISED Canada, 2018). To enhance and update CAR's analysis, we identified several additional domains of technological innovation by examining the products and processes of Canada's automotive technology companies and the primary areas of research expertise in Canada's automotive R&D centres and innovation incubators.

Based on our analysis of the main products, processes and automotive R&D activities in Canada's automotive technology organizations, we have enhanced CAR's automotive technology list to include the following ten trends:

1. *Autonomous Vehicle (AV) Technologies*: Autonomous vehicle technologies include the parts, software and technologies involved in achieving a level of driving autonomy in a vehicle. To identify the elements of this technology, we referred to SAE's Five Levels of Driving Automation and the University of Michigan's Centre of Sustainable Systems Autonomous Vehicles Scheme (SAE, 2019; CSS, 2019). Among the main autonomous vehicle technologies and parts, we identified the following:

    a. Sensors and data collection devices such as video cameras, Radio Detection and Ranging (RADAR) sensors, ultrasonic distance sensors, Infrared sensors and Light Detection and Ranging (LIDAR) sensors

b. Electronic control systems or AV controllers: the brain of the autonomous vehicle where all the sensors' data and feedback are collected, processed, analyzed and used for autonomous driving decision-making

c. Actuators: electromechanical parts that translate the control system's signals to mechanical actions such as steering, braking, and throttling

d. Autonomous Vehicle software: the software and algorithms involved in the AV system and its components such as embedded imaging and processing software for cameras, sensors and actuators, and driving automation algorithm codes.

e. Mapping & geographic information systems (GIS): high-definition geospatial maps and localization systems dedicated to providing autonomous vehicles with road dimensions and conditions; such maps guide AVs to their destinations and help throughout the navigation process (ESRI, 2020).

2. *Connected Vehicle Technologies*: Connected vehicle technologies refer to the devices, applications, and technologies that establish communication between a vehicle and its surroundings. Forms of vehicle communication include V2V – Vehicle to Vehicle, V2C – Vehicle to Cloud, V2I – Vehicle to Infrastructure, V2P – Vehicle to Pedestrians and V2X – Vehicle to Everything (CAAT, 2020). These communication forms help ensure the safety of a vehicle, its occupant(s) and its surroundings. They can also provide information that can ease traffic congestions, conserve energy and connect passengers through the Internet of Things (IoT).

   Under this category, we considered all automotive-related connectivity devices such as Dedicated Short-Range Communication (DSRC) modules for establishing wireless connections with the surrounding of a vehicle and Cellular vehicle-to-everything modules (C-V2X) for LTE or 5G connectivity for connections beyond the close proximity of a vehicle (IEEE, 2020). Also included in this technology group are all software design and development activities related to a vehicle's connectivity and communications.

3. *Artificial Intelligence & Machine Learning (AI & ML)*: Artificial Intelligence & Machine Learning are found in numerous automotive vehicle and production technology applications. Through a set of computational techniques and using datasets collected

from various sources, AI & ML allow machines to complete complex cognitive tasks and create algorithms and models that make predictions about future data based on previous data patterns (AMII, 2020). AI & ML allow computers and machines to perform specific tasks and simulate human intellectual and analytical capabilities. Examples of automotive AI & ML applications include predictive maintenance in vehicles and production systems, autonomous driving systems, and driver monitoring and assistance.

4. *Materials & Light Weighting*: A vehicle's mass plays a significant role in determining its overall fuel efficiency, handling and range. Therefore, it is unsurprising that there are continuous efforts in automotive manufacturing and research & development & innovation (R&D&I) to reduce the weight of the Body in White (BIW) and closures of a vehicle. Light weighting can be achieved by replacing high-density materials with alternative metals and composites (e.g. composites of aluminum, high-strength steel, magnesium and others) without compromising the material's strength (CAR, 2017). This automotive technology domain covers all manufacturing, research, development, simulation and testing activities necessary to improve automotive frame materials and light-weighting. It also covers all efforts to improve surface coating materials and their application procedures.

5. *Battery Electric & Hybrid Vehicle Technologies*: This category comprises all systems, parts and technologies involved in battery electric vehicles, hybrid vehicles and plug-in hybrid vehicles (AFDC, 2020). The two main elements in electric vehicle systems are:

   a. The electric powertrain includes electric traction motors, automatic transmissions, power electronics controllers, electric power converters and hybrid circuits.

   b. Energy management and storage devices in electric vehicles (for-which lithium-ion batteries are most commonly used); this includes the raw materials used in vehicle battery packs, battery management electronics and systems, on-board chargers and battery thermal management components.

6. *Hydrogen Fuel Cell (HFC) Technologies*: Fuel cells are energy conversion devices that generate electricity from compressed hydrogen and oxygen to power vehicles. The electricity generated from fuel cells feeds a battery that powers the vehicle's electric powertrain (CHFCA, 2016). HFC vehicles are zero-emission vehicles (ZEVs) that rely on the energy generated from the hydrogen fuel cells rather than the energy stored in batteries. HFCs are capable of powering vehicles ranging from passenger cars to pickup trucks, buses and heavy-duty trucks. HFC technological development domains include fuel cell stacks, fuel cell membranes and coating, hydrogen tanks, and hydrogen injection components.

7. I*nternal Combustion Engine (ICE) Powertrain Technologies*: covers all products, processes, research, development, testing, and simulation operations necessary for improving the functionality and efficiency of ICEs. There are several ways to enhance ICE fuel efficiency, such as improving fuel injection technologies and engine combustion processes, reducing pollutant emissions, and designing enhanced engine control and diagnostic modules.

8. *Production Technologies*: As detailed in a previous FOCAL report on the impact of Industry 4.0 on individual automotive manufacturing occupations, production technologies include the elements associated with the modern manufacturing system of Industry 4.0. Industry 4.0 technologies include: artificial intelligence, smart sensors, the internet of things (IoT), big data and analytics, cybersecurity, autonomous robotics, cloud computing, simulation, augmented reality and additive manufacturing (FOCAL, 2020).

9. *Vehicle Safety & Security*: With the expansion of the "cyber" element in most newly designed and manufactured vehicles, the concept of vehicle safety and security has expanded beyond the possibility of accidental failures in the mechanical, electrical and electronic systems of a car. Intentional “cyber” attacks targeting vehicles have become a real possibility. As a result, several preventative and protective systems have been developed to protect vehicles from malicious cyberattacks (Cui, 2017). Those include technologies and systems designed to address both the accidental and intentional aspects of a vehicle's safety and security. It also includes technologies such as cybersecurity software and systems for connected cars, mechanical and electronic failure predictive systems, and vehicle diagnostics safety systems.

10. *Other Software & Electronics*: includes all other advanced automotive software and electronics technology developments and trends. The majority of these technologies fall under in-vehicle technologies, including user interface (UI) and entertainment technologies (e.g., infotainment systems, advanced dashboard technologies and in-vehicle connectivity), and other advanced vehicle software or electronics do not directly relate to the technologies outlined above.

As a final note, we expect the technological fields listed above will remain relevant for at least the next ten years.

METHODOLOGY

Identifying Regional Automotive Technology Clusters

The methodology that we employed to identify Canada's automotive technology clusters involved the following steps. First, we built a comprehensive national database of 1,350 automotive manufacturing companies, automotive technology R&D organizations and technology incubators. The database includes: (1) assembly and automotive parts and manufacturing facilities, (2) current academic research labs, (3) government R&D and testing facilities, (4) not-for-profit automotive technology organizations, and (5) Canadian automotive technology partnerships. The establishment-level database includes relevant information on the product, manufacturing process and R&D focus of Canada's automotive technology organizations. The database also keeps a record of each organization's number of employees and other associated individuals.

To identify the emerging technologically oriented companies and organizations within the database, we used the list of the ten main automotive technologies highlighted in the preceding section. We selected companies and organizations which qualify under one or more of the technology categories. From our starting point of 1,350 automotive facilities, we identified 328 automotive technology organizations across Canada. Those organizations included private companies, government labs, academic research, partnerships and not-for-profit organizations.

To identify each automotive technology cluster in Canada, we used the list of the 328 organizations along with the data on their operations and employment. We ensured that each economic cluster met two main criteria (MEDJCT, 2019):

1. The presence of at least 15 facilities (including companies, academic labs, government facilities and partnerships) performing advanced automotive-related manufacturing, research & development or testing operations.

2. The presence of an anchor auto-tech company in the region with at least 500 employees.

Employment in the Automotive Technology Clusters

To determine the number of employees and individuals associated with Canada's six automotive technology clusters, we employed an establishment-level analysis. In carrying out our analysis, we accounted for the employees of automotive technology companies and the researchers and other professionals associated with academic institutions, government facilities, not-for-profit organizations and research partnerships. Our analysis differs from previous reports produced by the FOCAL Initiative that account for the total employment in the broader automotive manufacturing sector. Those reports employed both a top-down and bottom-up analysis. The top-down analysis entailed an examination of the economic linkages between non-automotive and automotive NAICS codes to better understand employment in the broader automotive manufacturing sector, while the bottom-up analysis involved the use of enterprise-level data to validate the employment numbers in the automotive manufacturing sector.

In this series of reports, we employ a bottom-up (or an enterprise-level analysis) to account for the total number of employees and associated individuals working within each automotive technology cluster. Our rationale for doing so is twofold. First, while the top-down approach accurately captures economic transactions and linkages within the broader automotive manufacturing sector, many of the R&D operations and partnerships within companies, institutions and labs can only be captured through a bottom-up approach. Second, through a bottom-up analysis of employment in Canada's automotive technology clusters, the scope of what is considered automotive employment can be broadened to encompass all individuals active in research, development, innovation and testing activities. In our analysis, in addition to accounting for the salaried and hourly employees working for automotive companies, we included individuals and workers associated with universities, colleges, government facilities, partnerships and not-for-profit organizations. As we identify in our reports, university and college-led projects contribute a significant number of employees and associated individuals (e.g., faculty members, researchers and lab technicians) to Canada's automotive industry.

As a final note, it is worth mentioning that many of the emerging technology organizations that we identify in our analysis carry-out diversified manufacturing, research, development and innovation activities. That is, they may cater to the automotive industry and other sectors in the Canadian economy. Therefore, it is possible that in some organizations, employees may be engaged in developing new automotive technologies and innovation activities related to other sectors.

Profiling Technology & Skills in the Automotive Technology Clusters

Our analysis of Canada's automotive technology clusters identifies: (1) the distribution of facilities by technology, (2) the distribution of employees and associated individuals by technology, and (3) the occupational distribution for the automotive-related highly skilled occupations.

To identify the highly skilled occupations in each cluster, we referred to previous FOCAL Initiative reports. The FOCAL Initiative previously identified 49 relevant occupations in the Canadian automotive sector based on either the number of employees in the occupation or the job's technical skills. Our analysis of Canada's automotive technology clusters identified 41 automotive-related occupations with at least 100 employees; 8 additional occupations were recognized based on their technical skillset and contribution to either automotive manufacturing or R&D.

Within each automotive technology cluster, we conducted our occupational distribution analysis on 18 highly skilled occupations. As shown in table 1, those 18 occupations were selected from the FOCAL Initiative's list of automotive 49 occupations. Our analysis included those occupations due to the importance of their skillsets for developing the emerging automotive technologies under study.

It should be noted that while this study has narrowed the analysis to 18 highly skilled occupations, our reports condensed the occupations into 3 main groups: Management

Occupations, Engineering Occupations and Engineering Technicians and Technologists Occupations.

Table 1. List of 18 highly skilled automotive-related occupations selected for the occupational distribution analysis

NOC Code	Occupation
0211	Engineering managers
0213	Computer and information systems managers
0911	Manufacturing managers
2132	Mechanical engineers
2133	Electrical and electronics engineers
2141	Industrial and manufacturing engineers
2142	Metallurgical and materials engineers
2147	Computer engineers (except software engineers and designers)
2171	Information systems analysts and consultants
2172	Database analysts and data administrators
2173	Software engineers and designers
2174	Computer programmers and interactive media developers
2232	Mechanical engineering technologists and technicians
2233	Industrial engineering and manufacturing technologists and technicians
2241	Electrical and electronics engineering technologists and technicians
2243	Industrial instrument technicians and mechanics
2281	Computer network technicians
2283	Information systems testing technicians

To identify each cluster's occupational distribution, we conducted a survey of job titles and occupations for the employees working within the companies in our database. The survey was undertaken only for the private companies and excluded all individuals in academic labs, government facilities, partnerships and not-for-profit organizations. We used company websites and LinkedIn's Recruiter tools to survey the job titles and occupations of the relevant employees. Our analysis considered a sample of profiles large enough to achieve a 95% confidence level and a 5% error margin and used the Employment and Social Development Canada’s (ESDC) National Occupational Classification (NOC) website to associate each job title with its corresponding designated occupation.

SUMMARY & OVERVIEW OF RESULTS

In this section, we summarize the main results of the cluster reports. The purpose of this summary is to provide an overview of the total number of organizations in Canada's automotive technology clusters. It also identifies the number of employees and individuals associated with each cluster and its top three technology focus areas. The summary and overview of our results is presented in Table 2.

Table 2 shows that there are a total of 298 organizations operating within Canada's six automotive technology clusters.[2] Within those 298 automotive technology organizations, there are 29,078 employees engaged in automotive technology manufacturing and R&D activities. By employment count, the three largest automotive technology clusters in Canada are (1) the Greater Toronto and Hamilton Area (GTHA), (2) Ottawa and (3) the Greater Montreal Area (GMA). The 'top three technology' focus section of Table 2 underscores that in aggregate Canada's automotive technology clusters benefit from an abundance of skill and talent necessary for the development of autonomous, connected, and electrified vehicle technologies. It also shows that Canada is home to numerous organizations that specialize in the design, development and testing of new production technologies such as those associated with Industry 4.0. Beyond that, it illustrates that Canada's auto-tech clusters specialize in different technological domains. For instance, while the cluster of companies and organizations in the GTHA specialize in autonomous, connected and electrified vehicle technologies, the auto-tech cluster in Windsor excels in the R&D associated with new production technologies, ICE powertrain improvements, and vehicle lightweighting.

[2] On page 9, we reported that we identified 328 automotive technology organizations in our Canada-wide database. Of those 328 organizations, 298 were identified in the six automotive technology clusters under study.

Table 2. Summary & overview of the main results and findings in each of the automotive technology clusters

Cluster	Number of Automotive Companies & Organizations	Direct Automotive Technology Employment	Top 3 Technology Focus Areas
Greater Toronto-Hamilton Area (GTHA)	83	13,048	(1) Autonomous Vehicle Technologies (2) Battery Electric & Hybrid Vehicle Technologies (3) Connected Vehicle Technologies
Kitchener-Waterloo-Cambridge (KWC)	65	1,850	(1) Autonomous Vehicle Technologies (2) Connected Vehicle Technologies (3) Production Technologies
Ottawa	44	8,210	(1) Autonomous Vehicle Technologies (2) Connected Vehicle Technologies (3) Vehicle Safety & Security
Windsor	21	801	(1) Production Technologies (2) ICE Powertrain Technologies (3) Materials & Light Weighting
Greater Montreal Area (GMA)	59	3,269	(1) Battery Electric & Hybrid Vehicle Technologies (2) Artificial Intelligence & Machine Learning (3) Production Technologies
Vancouver	26	1,900	(1) Hydrogen Fuel Cell Technologies (2) Battery Electric & Hybrid Vehicle Technologies (3) Connected Vehicle Technologies
Total	**298**	**29,078**	

This report outlined the ten automotive technology domains and the methodology that we employed to identify Canada's automotive technology clusters. Further details on Canada's automotive technology clusters can be found in our individual reports on Vancouver, the GTHA, KWC, Windsor, Ottawa and the GMA. Those reports identify each cluster's main technology focus areas and profiles their occupational distribution and skills.

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