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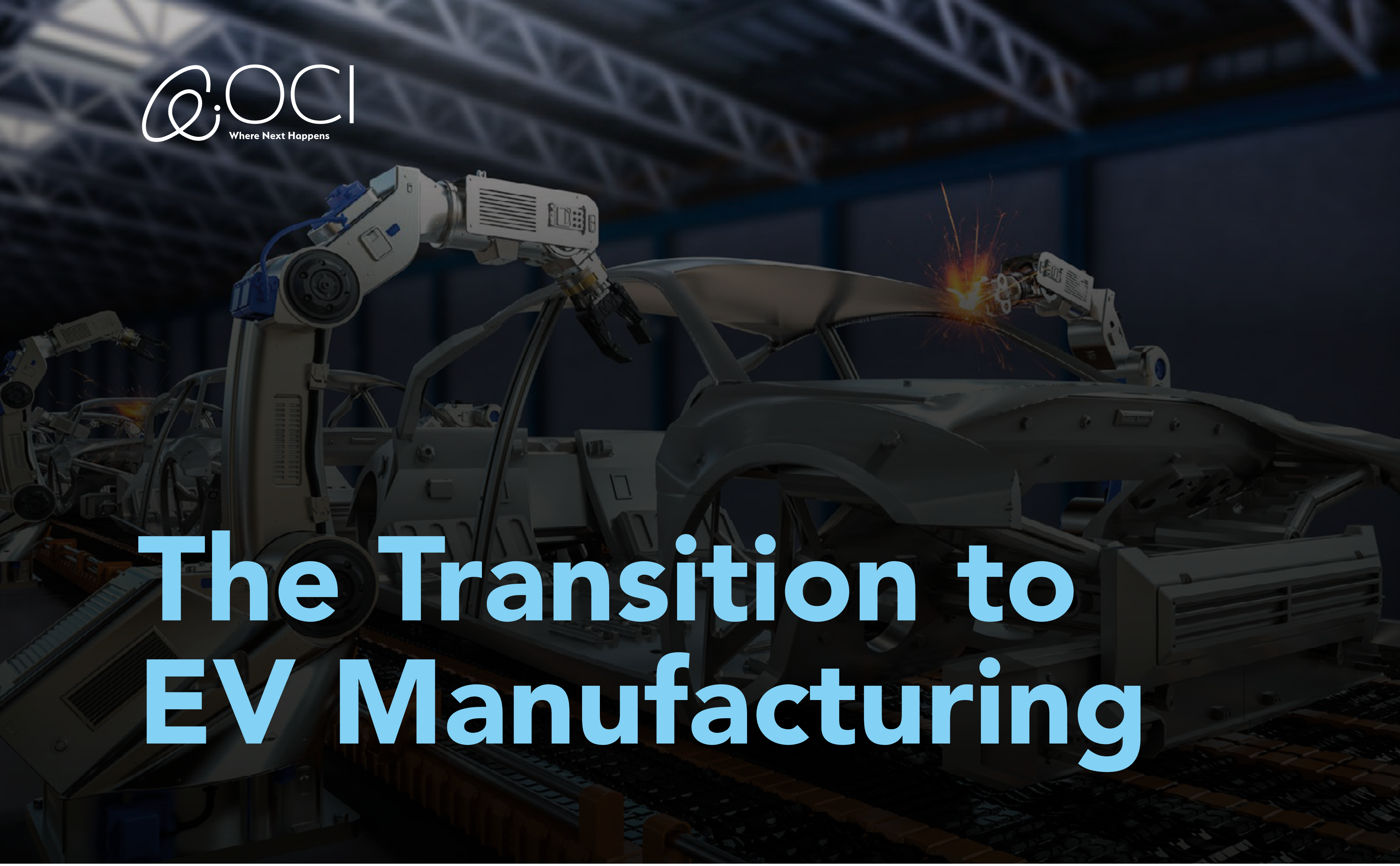

The Transition to EV Manufacturing

Canada

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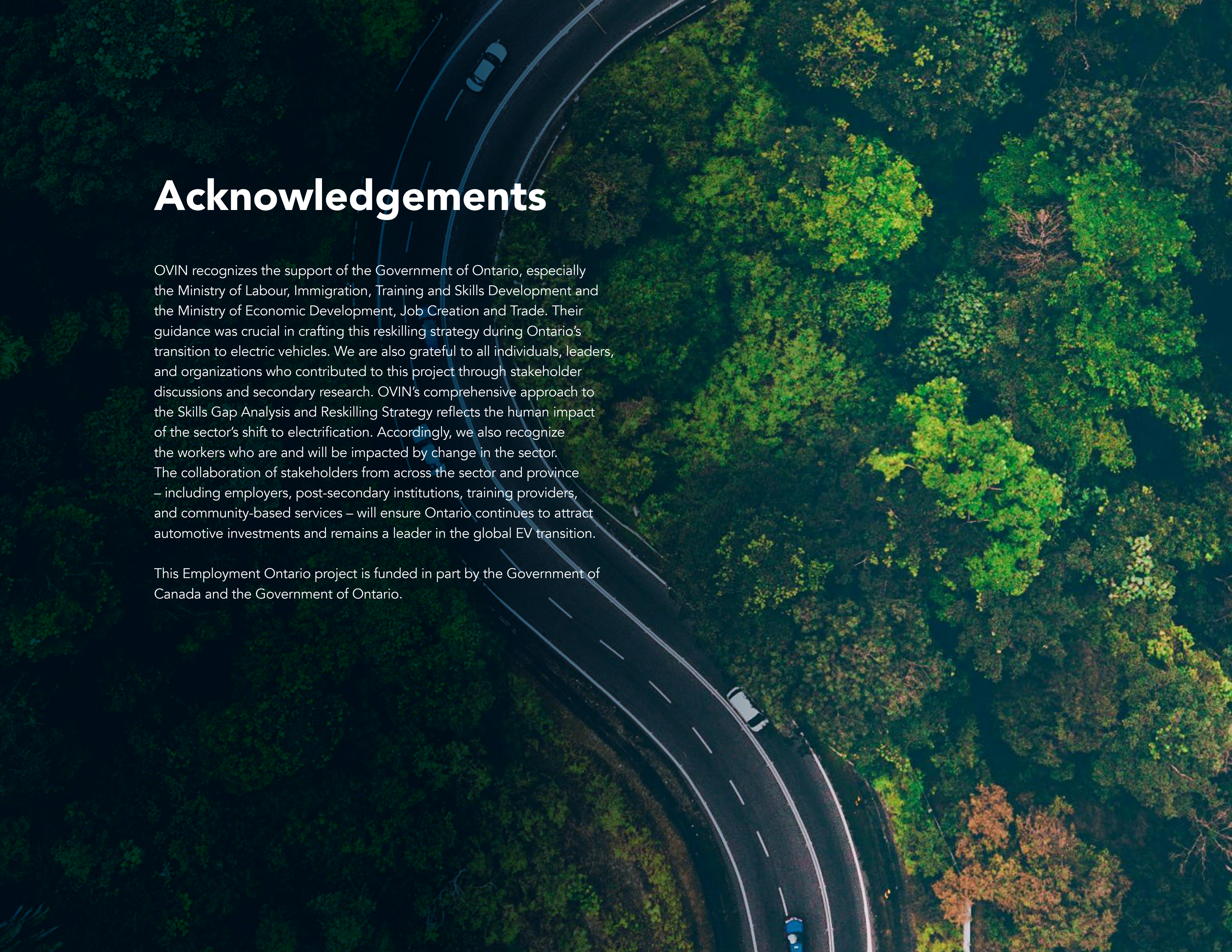

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Skills and Knowledge Needed for Ontario's EV Transition:

Gaps and Opportunities

Contents

Executive Summary

The automotive sector is entering a phase of unprecedented change, largely driven by the push for sustainability and the evolving regulatory landscape aimed at combating climate change. As original equipment manufacturers (OEMs) pivot towards increasing their production of electric vehicles (EVs), the shift is set to reshape the future of Ontario's auto industry.

As a recognized leader in North American auto production, Ontario plays a pivotal role in the EV transition. Significant investments have been made by global automotive companies to build a robust EV supply chain in the province. These investments are driving the retooling of internal combustion engine vehicle (ICEV) manufacturing facilities, positioning Ontario to lead in EV production.

While several manufacturing processes will carry over from ICEV to EV production, other key tasks and roles will experience dramatic transformations. This report explores how this shift will impact the workforce and identifies the necessary skills, knowledge, and competencies for the future of auto production.

A certain number of occupations are common to both ICEV and EV production. We find that workers in these positions have highly transferable skills. However, we identify several important gaps in EV knowledge for these occupations. Some are net-new types of knowledge about electric vehicles, electricity and EV batteries individuals need to acquire. Other gaps are partial and relate to knowledge that ICEV workers already have, but need to update to account for how EVs work. This applies to both vehicle and production components.

Positions related to EV batteries, electric motors and power electronics are unique to EV production and do not currently exist in ICEV manufacturing. Given the highly scientific and technical nature of some of these roles (e.g., chemists and chemical engineers), these positions are likely to be filled externally.

By identifying transferable skills and knowledge gaps workers could face amid the EV transition, this report seeks to inform opportunities for training and reskilling in the automotive sector. The information in this report constitutes the foundation for OVIN's Reskilling Training Framework, which will support employers in transitioning their workforces to EV production by closing the gaps to ensure no auto worker is left behind.

Introduction

The automotive sector plays a crucial economic role as an employer in Ontario. In 2023, 31,563 people worked in motor vehicle manufacturing in the province. Another 67,176 were employed in motor vehicle parts manufacturing. Taken together, these nearly 100,000 jobs represented 8.4 per cent of total employment in goods-producing industries in Ontario[1].

As countries seek to reduce greenhouse gas emissions and combat climate change, the auto sector as a whole is going through an unprecedented transition. As demand increases and sales mandates come into force in some jurisdictions, original equipment manufacturers (OEMs) are transitioning from internal combustion engine vehicles (ICEVs) to electric vehicles (EVs).

Ontario is strategically positioned in this transition due to its long tradition of auto manufacturing and its skilled workforce. The 2024 Ontario budget noted that "right here in Ontario, manufacturers are making new investments across the emerging electric vehicle (EV) supply chain to help the province become a North American hub for building the cars of the future[2]".

As OEMs adjust to manufacturing EVs, workers must also adapt. Some roles and tasks will dramatically change (for instance those related to engine assembly) while others may become obsolete. EVs have unique components like batteries and electric motors, which will lead to the emergence of new roles like chemical engineers and electric motor controls engineers. This report looks at this dynamic to assess the skills and knowledge workers need to transition from ICEV to EV manufacturing. It highlights when skills and knowledge are transferable from one type of vehicle production to another and when gaps are present.

This report seeks to inform opportunities for training and reskilling in the automotive sector. This information is essential to help employers retain their workforce amid the EV transition. It can also assist employers in determining when new EV occupations should be filled externally due to the new skills and knowledge required.

What Is an Occupation, a Skill and a Knowledge?

Occupation

Whereas there is virtually no limitation to what a job title can be, the names of occupations are formally categorized and defined under the National Occupational Classification (NOC) system. Occupations and occupation codes in this report are based on the 2021 NOC system.

Statistics Canada describes an occupation as the "kind of work performed in a job, a job being all the tasks carried out by a particular worker to complete his or her duties. An occupation is a set of jobs that are sufficiently similar in work performed. Kind of work is described in terms of tasks, duties and responsibilities[3]". Each occupation is associated with a specific set of skills and knowledge.

Skill

The term "skill" tends to be used loosely in job postings. However, skills are different than knowledge. This report uses the definition of the Skills and Competencies Taxonomy from Employment and Social Development Canada (ESDC). It defines skills as "developed capabilities that an individual must have to be effective in a job, role, function, task or duty[4]". Examples of skills include writing, critical thinking and problem solving.

Knowledge

In ESDC's taxonomy, knowledge is defined as "organized sets of principles and practices used for the execution of tasks and activities within a particular domain[5]". A knowledge can pertain to specific domains like education, health and wellbeing or natural resources[6]. Other knowledge can be general and transcend specific domains. Languages like English and French constitute good examples.

1. Difference Between ICEV and EV Manufacturing

To analyze how the transition to EVs impacts occupations and workers, we begin by reviewing the high-level phases involved in the manufacturing of ICEVs and EVs.

The traditional process to build an ICEV has eight phases. It starts with design and engineering. Building on previous editions of the vehicle and constant research and development (R&D), the OEM designs the car and its characteristics (e.g., mechanical, safety features and aesthetic features). A list for material and parts procurement originates from this stage.

The in-facility manufacturing process starts with stamping, which involves cutting and shaping flat metal sheets. These shaped pieces are then brought to the body shop station where they are welded together to form the chassis and the body of the car. Once assembled, this empty vehicle structure is taken to the paint shop where it gets sealed and then painted with a primer. The basecoat (the actual colour of the car) and a clearcoat are subsequently applied.

The powertrain includes the engine and is usually prepared in parallel with the aforementioned phases. Once ready, it is brought to the main assembly line to be installed in the painted vehicle. Beyond the engine itself, the remaining major components are assembled during this phase.

This includes, but is not limited to:

- Transmission system (including the gearbox)
- Brakes
- Fuel system (e.g., fuel tank, pump and line)
- Exhaust system (e.g., exhaust pipe, muffler and catalytic converter)
- Interior components like seats

Wheels and tires are assembled last, at which point the car can come off the assembly line and rest on the ground. The last phase of the manufacturing process is fundamental from a quality and safety standpoint. This is when the vehicle will be inspected and tested. A series of quality controls is also performed.

Manufacturing Process of an ICEV

1.1. How Is EV Manufacturing Different?

At a high level, the eight phases to produce ICEVs are also required for EVs. However, the nature of the tasks involved for some of these phases changes.

The EV supply chain is substantially different compared to ICEVs. At a foundational level, critical minerals like lithium and nickel are required to make the batteries that power EVs. To secure the domestic supply of these resources (which can be found in the northern regions of Canada), both the Ontario and federal governments launched critical minerals strategies[7].

Battery manufacturing occurs in a separate location from where EVs are produced. While this report is focused on vehicle manufacturing, the spotlight text box provides an overview of the EV battery manufacturing sector along with its occupations.

The EV battery packs are usually mounted onto the vehicle's chassis at the vehicle production facility. To prevent them from overheating, a battery thermal management system must be installed. Workers who put the body of the car on the chassis must consider the presence of battery packs during the body shop phase.

Given the distinct nature of an electric engine, the preparation of the powertrain is obviously different and involves different components (for instance, EV motors do not need oil and spark plugs). Once the electric engine is added to the vehicle on the main assembly line, several "traditional" parts are not needed (e.g., fuel and exhaust systems) or will be different. As an example, EVs do not have multiple gears like ICEVs, which means the transmission and the gearbox that get installed are completely different.

EVs also require the installation of parts and systems that are unique to them. In addition to battery packs and the charging intake unit, EVs need several power electronics and electric components. These include a motor controller, a thermal management system, converters, inverters and high-voltage wiring[8]. These relatively new and, in some cases, potentially dangerous components require employees to have robust EV battery safety awareness and knowledge.

Spotlight on EV Battery Manufacturing

The EV battery manufacturing process has three specific phases: upstream, midstream and downstream. It starts upstream with the extraction of the minerals needed to make the batteries. This includes lithium, nickel, cobalt and graphite. The minerals are then processed and refined at the midstream stage to attain the level of purity needed. The output is used to produce anode and cathode materials, which are essential to prepare battery cells.

The downstream phase usually begins once the battery cells have been manufactured. EV battery manufacturing plants take different approaches to sourcing battery cells. Some are integrated and produce the cells on-site while others get them from a supplier. The battery cells are cleaned and assembled into modules and then into packs during the downstream phase. A battery management system and other functional components are usually added to the battery pack. Batteries are also tested downstream.

Occupations in the Downstream Phase

Several international companies are building EV battery plants in Canada with the support of the provincial and federal governments. Once operational, these facilities will employ thousands of individuals.

Leveraging job postings from major EV battery projects[9] and the EVcareers.ca platform, the table below identifies the occupations that will be required for the production process. Positions in business areas adjacent to the production function are also included (e.g., safety and environment, research and development and quality).

Occupations in EV Battery Manufacturing

Business Area	Occupation	Occupation Code	Example of Job Titles
Safety and Environment	Industrial and Manufacturing Engineers	21321	• Battery Safety Engineer
	Occupational Health and Safety Specialists	22232	• Electrical Safety Specialist • Health and Safety Manager • Process Safety Specialist
	Public and Environmental Health and Safety Specialists	21120	• Environmental Specialist
Research and Development	Chemical Engineers	21320	• Chemical Engineer
	Chemists	21101	• Chemist
	Electrical and Electronics Engineers	21311	• Battery Pack Design Engineer
	Engineering Managers	20010	• Mechanical Validation Engineer
	Industrial and Manufacturing Engineers	21321	• Automation Engineer • Battery Innovation Engineer • Integration Equipment Engineer • Material Engineer
	Mechanical Engineers	21301	• Battery Mechanical Design Engineer
Production	Chemical Technologists and Technicians	22100	• Chemical Technologist and Technician
	Electrical and Electronics Engineers	21310	• Battery Electric Vehicle Calibration Engineer • Battery Management System Elect. Design Release Eng. • Electrical Design Engineer
	Engineering Managers	20010	• Industrial Engineer Manager
	Industrial and Manufacturing Engineers	21321	• Industrial Engineeer • Manufacturing Engineer • Process Engineer • Production Engineer • Technical Project Manager

Occupations in EV Battery Manufacturing
(continued)

Business Area	Occupation	Occupation Code	Example of Job Titles
Production *(continued)*	Industrial engineering and manufacturing technologists and technicians	22302	• Production Technician
	Mechanical Engineers	21301	• Mechanical Engineer
	Mechanical Engineering Technologists and Technicians	22301	• Instrument Technician
	Software Engineers and Designers	21231	• Battery Software Engineer
	Tool and Die Makers	72101	• Toolmaker
Quality	Electrical and Electronics Engineers	21311	• Battery Formation/Test Engineer • Battery Pack Test Engineer • Lithium Ion Cell/Module Application Engineer
	Engineering Managers	20010	• Battery Pack Testing Supervisor • Lean Engineer • Six Sigma Master Black Belt
	Industrial and Manufacturing Engineers	21310	• Cell Quality Engineer • Operational Excellence Specialist • PFMEA & DFMEA Expert Engineer • Quality Laboratory & Monitoring Engineer • Shopfloor Quality Engineer
	Industrial engineering and manufacturing technologists and technicians	22302	• Cell Quality Technician

2. ICEV Manufacturing: Occupations and Associated Skills and Knowledge

The production of ICEVs requires workers with different skills across the eight phases identified in section 1. Our research identified over 50 job titles in ICEV manufacturing. These positions are captured by 26 different five-digit occupations (the complete list can be found in Appendix A). This section identifies the skills and knowledge that are the most common across these 26 occupations in ICEV manufacturing.

Looking at the skills category, communication skills are the most in demand. It appears as a top 10 skill requirement in job postings for 22 of the 26 occupations. It is followed by other soft skills such as teamwork, leadership, organizational skills and interpersonal skills.

Knowledge related to languages is in high demand. English language tops the list with 22 of the 26 occupations having it as a top 10 knowledge requirement. Bilingualism and French language are tied for second place.

Beyond languages, other in-demand knowledge includes blueprint reading and quality assurance. A knowledge of occupational health and safety acts is also required for several occupations.

Top 10 Skills and Knowledge[10]

Skill	Knowledge[11]
1. Communication skills	1. English language
2. Teamwork	2. Bilingual
3. Leadership	2. French language
4. Organizational skills	4. Blueprint reading
5. Interpersonal skills	4. Quality assurance
6. Problem solving	6. Occupational health and safety Act
7. Customer service	7. Budgeting
8. Planning	8. Inventory Management
9. Decision-making	9. Agile Software Development
10. Troubleshooting	9. Key Performance Indicators
	9. Lean Manufacturing

2.1. What Does the EV Transition Mean for ICEV Occupations?

Several occupations are common to both ICEV and EV manufacturing. This is particularly true for workers involved in the stamping, body shop and paint shop phases, which will not experience major disruptions amid the EV transition. For the most part, the tasks required for these phases do not dramatically change from one type of vehicle to another. More details on occupations common between ICEV and EV production is provided in section 3.1.

However, what individuals need to know and do for the three final phases of vehicle production (i.e., powertrain assembly, main assembly line and inspection, tests and quality control) will change substantially. Knowledge about certain ICEV components will no longer be required as they are not present in EVs (e.g., exhaust system). Other components like the powertrain will still exist, but they will be completely different (we elaborate on the partial knowledge gaps that result from this in section 3.1.2).

Several occupations in the automotive sector will evolve as a result of the EV transition. However, given their broad and encompassing nature, occupations needed in ICEV manufacturing will not necessarily disappear in the EV context. For instance, the job title of a person who installs exhaust systems in ICEVs is "assembler" and the occupation is "motor vehicle assemblers, inspectors and testers". Both the job title and the occupation will continue to exist in EV manufacturing, but these individuals will install other components. To capture the impacts of the EV transition on ICEV workers at a more granular level, it is therefore more accurate to look at specific tasks and roles.

As OEMs pivot to EV manufacturing, workers on the powertrain and main assembly lines will no longer perform certain tasks, including:

- Installing spark plug, fuel injector, oil pan and intake manifold to the engine
- Installing and connecting alternator to engine
- Installing fuel system
- Installing exhaust system

Accordingly, the workers performing these tasks in the ICEV manufacturing process are those whose roles are most at-risk of disruption in the transition to EV manufacturing. Workers who assemble traditional ICEV powertrain components would need to acquire knowledge related to EVs and electric motors to transition. With the proper reskilling, they could potentially work on an EV powertrain assembly line. Individuals who install fuel and exhaust systems could face a more challenging transition. While some could be redeployed on the main assembly line to support the installation of other non-electrical parts and systems, others would need more substantial reskilling to perform new tasks related to electrical components. Alternatively, some individuals could be redeployed elsewhere along the manufacturing process.

Given their absence in EVs, inspecting and testing the components mentioned above during the last phase of the manufacturing process will not be required. Instead, workers will have to learn how to inspect and test new EV and power electronics components such as batteries, motor controllers, converters and inverters and charge ports. Beyond the knowledge of these parts and the testing tools, this will require people to gain a high degree of electric safety awareness.

Overall, EVs have fewer parts than ICEVs. The literature does not agree on whether this means EV plants will require fewer employees. An article from Carnegie Mellon University summarizes the state of the debate in the following terms: "previous studies and industry statements on the employment implications of the transition to EVs have been mixed, with some indicating that BEV manufacturing is less labor intensive than ICEV manufacturing, and others supporting that they are comparable[12]." Focusing on OEMs and Tier 1 suppliers, the authors of this particular article find that more labour is needed to produce EV powertrains compared to ICEV equivalents if one includes the battery manufacturing process[13].

3. EV Manufacturing: Occupations and Associated Skills and Knowledge

Excluding the battery production and aftermarket segments, the EVcareers.ca platform identifies 51 job titles involved in the production of electric vehicles. These positions can be grouped under 32 different five-digit occupations (the complete list can be found in Appendix B). Approximately a third of them (11) were engineer and engineering technologist and technician occupations. These positions were spread across several fields of engineering, including chemical, electrical, industrial and mechanical.

EV manufacturing workers must possess a wide array of skills and knowledge. Based on the requirements listed for each of the 51 jobs, we identified in total nearly 150 different skills and knowledge. Types of knowledge accounted for over three quarters of this number.

Looking across all EV positions, management is the most common skill needed. It is followed by communication and support skills. Problem solving, interpersonal skills and written communication round up the top 5.

As for the knowledge category, integration is the most-commonly required type of knowledge. Unsurprisingly, given the crucial role of electricity and batteries in EVs, electrical engineering is the second most common knowledge. It is tied with calibration. Powertrain and operations are also tied for fourth place.

Top 10 Skills and Knowledge Involved in EV Manufacturing[14]

Skill[15]	Knowledge[16]
1. Management skills	1. Integration
2. Communication skills	2. Calibration
3. Support skills	2. Electrical engineering
4. Problem solving	4. Operations
5. Interpersonal skills	4. Powertrain
5. Written communication	6. Mechanical engineering
7. Leadership	7. Driving
8. Planning	7. Requisition
8. Oral communication	9. Propulsion
10. Data analysis	10. Electric vehicle
	10. Electronics

3.1. Occupations Common to ICEV and EV Production

Based on our methodology and the data available, 14 occupations can be found in both ICEV and EV production. However, the nature of the skills and knowledge each occupation must possess changes depending on the type of vehicle manufactured.

3.1.1. Skills

Leveraging a matrix to match skills (see the "Methodology" section for more details), we find that occupations common to both ICEV and EV production have highly transferable skills. In this regard, ICEV workers in these occupations have almost all the skills required to hold similar roles in an EV plant. These transferable skills are identified in the table below.

Skills Transferable Between ICEV and EV Production

Occupation*	Occupation Code	ICEV Skill with Match in EV Manufacturing
Electrical and electronics engineering technologists and technicians	22310	• Communication skills • Customer service • Teamwork
Electrical and electronics engineers	21310	• Communication skills • Customer service • Interpersonal skills • Leadership • Problem solving • Project management • Teamwork
Electricians (except industrial and power system)	72200	• Decision making • Problem solving
Engineering managers	20010	• Communication skills • Organizational skills • Planning • Problem solving • Supervisory skills • Teamwork

Skills Transferable Between ICEV and EV Production *(continued)*

Occupation*	Occupation Code	ICEV Skill with Match in EV Manufacturing
Industrial and manufacturing engineers	21321	• Communication skills • Interpersonal skills • Leadership • Organizational skills • Planning • Problem solving • Project management • Teamwork • Trouble shooting
Machining tool operators	94106	• Communication skills • Leadership • Time management • Trouble shooting
Machinists and machining and tooling inspectors	72100	• Communication skills • Leadership • Organizational skills • Problem solving • Trouble shooting • Written communication
Manufacturing managers	90010	• Communication skills • Customer service • Interpersonal skills • Leadership • Organizational skills • Planning • Problem solving • Project management • Teamwork

Skills Transferable Between ICEV and EV Production *(continued)*

Occupation*	Occupation Code	ICEV Skill with Match in EV Manufacturing
Mechanical engineering technologists and technicians	22301	• Communication skills • Project management • Teamwork • Written communication
Mechanical engineers	21301	• Communication skills • Interpersonal skills • Leadership • Problem solving • Project management • Teamwork
Production and transportation logistics coordinators	13201	• Communication skills • Customer service • Leadership • Organizational skills • Planning • Time management

*Occupations for which skill data was not available in the context of ICEV or EV manufacturing (or both) were not included in this table:

- Contractors and supervisors, machining, metal forming, shaping and erecting trades and related occupations
- Motor vehicle assemblers, inspectors and testers
- Supervisors, motor vehicle assembling

Data analysis skills are a notable exception to skill transferability for several of the occupations identified above. The ability to work with data comes up as a relatively common requirement in EV production. While some ICEV workers also need data analysis skills, they appear to play a larger and more central role in the context of EV manufacturing. Some EV jobs such as data analysts and data scientists are specifically focused on data analysis.

3.1.2. Knowledge

While we observe high transferability on the skill side, occupations common to ICEV and EV manufacturing present extensive EV knowledge gaps. These knowledge gaps can be grouped into two categories.

First, there are knowledge requirements that are net-new for certain occupations in the EV context. We label them "net-new gaps". ICEV workers currently in these occupations do not possess this knowledge and would need to acquire it to transition to EV manufacturing. These net-new gaps pertain to electric vehicles, electricity and EV batteries. Notably, several occupations will also need to acquire knowledge of electrical engineering.

EV production requires many workers to have expertise related to electricity. This is an essential type of knowledge for those involved in the engineering and assembly of electric motors and power electronics. However, it is also important for workers who put the car together on the main assembly line as well as individuals who perform inspections, tests and quality control. Beyond the technical expertise, an awareness of the safety risks associated with electricity as well as high voltage and batteries is important for all workers in an EV manufacturing facility.

The second type of gap relates to knowledge that ICEV workers already have, but need to update to account for the unique characteristics of EVs. In this regard, they can be categorized as "partial knowledge gaps". This category of gaps applies to both vehicle and production components. For instance, individuals working in ICEV manufacturing already have a knowledge of transmission systems. However, this vehicle component is different in EVs (ICEVs have multi-speed/gear transmissions whereas EVs usually have single-speed/gear transmissions). Similarly, the integration of EV systems during the assembly process is substantially different.

The knowledge gaps of the occupations that are common to both ICEV and EV manufacturing are identified in the table below.

Knowledge Gaps Between ICEV and EV Production

Occupation*	NOC Code	Net-New Gap	Partial Gap
Electrical and electronics engineering technologists and technicians	22310	• Battery management • Computer engineering • Electric motor • Electric vehicle	• Electronics • Voltage/High voltage
Electrical and electronics engineers	21310	• Battery pack • Electric vehicle • Mechanical engineering	• Electronics • Integration • Powertrain • Propulsion • Transmission systems • Voltage/High voltage
Electricians (except industrial and power system)	72200	None	• Installation • Integration
Engineering managers	20010	None	None
Industrial and manufacturing engineers	21321	• Electrical engineering	• Integration • Powertrain • Propulsion
Machining tool operators	94106	• Electric motor	• Axles • Integration • Powertrain • Subsystems • Transmission system
Machinists and machining and tooling inspectors	72100	• Electric motor	• Axles • Integration • Powertrain • Subsystems • Transmission system
Manufacturing managers	90010	• Battery pack • Electrical engineering • Electric vehicle	• Electronics • Integration • Powertrain • Propulsion

Knowledge Gaps Between ICEV and EV Production *(continued)*

Occupation*	NOC Code	Net-New Gap	Partial Gap
Mechanical engineering technologists and technicians	22301	• Electrical engineering	• Chassis • Integration
Mechanical engineers	21301	• Battery pack • Electrical engineering • Electric vehicle	• Electronics • Integration • Powertrain • Propulsion
Motor vehicle assemblers, inspectors and testers	94200	• Electricity	None
Production and transportation logistics coordinators	13201	None	None

*Occupations for which knowledge data was not available in the context of ICEV or EV manufacturing (or both) were not included in this table:

- Contractors and supervisors, machining, metal forming, shaping and erecting trades and related occupations
- Supervisors, motor vehicle assembling

3.2. Occupations Unique to EV Manufacturing

Given the unique characteristics of electric vehicles, there are several jobs that are specific to EV production. Most of these positions pertain to EV batteries, electric motors and power electronics.

Even though most OEMs receive pre-assembled battery packs, chemistry is an important dimension of EV manufacturing. The role in-house chemists, chemical engineers and chemical technologists and technicians play is new in the context of automotive manufacturing. While the skills of these individuals overlap with other ICEV occupations (see table below), their specialized knowledge and expertise in chemistry do not exist among the traditional automotive workforce. As a result, reskilling is not really an option given the highly scientific and technical nature of these roles. OEMs must hire externally to fill these positions.

Despite also being unique to EV production, the "assemblers and inspectors, electrical appliance, apparatus and equipment manufacturing" occupation could potentially be filled by ICEV workers in an adjacent role. If provided with the right training on electricity and electrical parts, individuals working as "motor vehicle assemblers, inspectors and testers" in ICEV production could be a strong fit. Both occupations have similar education requirements (high school)[17], which would facilitate the transition. While they would need to acquire specific EV-related knowledge, ICEV workers in motor vehicle assembler, inspector and tester roles would not have to go back to school for a prolonged period to get a new degree to fill the EV occupation of assemblers and inspectors, electrical appliance, apparatus and equipment manufacturing.

We grouped the EV-specific job titles identified in the EVcareers.ca tool into five-digit occupations. The skills and knowledge required for the EV occupations that do not have an ICEV equivalent are listed in the table below. It should be noted that several EV job titles fall under five-digit occupations that also exist in ICEV production. For instance, job titles like "electric motor controls engineer" and "power electronics subject matter expert" are captured under "electrical and electronics engineers" occupation. In this regard, some job titles are unique to EV production, but their associated occupations are not.

Skills and Knowledge of EV-Specific Occupations

Occupation*	Occupation Code	Skill	Knowledge
Chemical engineers	21320	• Communication skills • Management skills • Oral communication • Planning • Support skills • Written communication	• Airflow • Batteries • Battery management • Battery Pack • Cleanrooms • Electrical engineering • Electrode • Electronics • Failure mode and effects analysis • Integration • Operations • Requisition
Chemical technologists and technicians	22100	• Management skills • Communication skills • Oral communication • Planning • Problem solving • Research • Support skills	• Calibration • Destructive testing • Operations • Process improvements • Quality control • Requisition • Software maintenance

*Two EV-specific occupations were not included in this table due to the absence of data on the skills and knowledge they require:

- Assemblers and inspectors, electrical appliance, apparatus and equipment manufacturing
- Chemists

Tools and Technologies in EV Manufacturing

Sometimes mislabeled as "technical skills", tools and technologies were carved out of this report. Given the early stages of EV production and the data publicly available, requirements for EV tools and technologies are evolving and are not currently well-established. This makes robust occupation-by-occupation comparisons difficult at this stage.

However, at a high level, it is expected that the ability to use, install and even program digital tools and technologies (sometimes loosely defined as "digital skills") will become increasingly important in EV manufacturing. For instance, EV workers will have "to interact with human-machine interfaces, analyze and manage data, and utilize specialized knowledge of vehicle technologies and systems thinking[18]." Similarly, individuals with software expertise will be needed to install hardware and software specific to EVs[19].

Conclusion

As the EV transition continues in Ontario, the nature of the auto manufacturing process is evolving. While some production phases may not experience radical changes, others like the powertrain assembly and the main assembly line stage will require different tasks and expertise.

The report assessed ICEV and EV manufacturing occupations and their respective skills and knowledge. We found that most skills required in ICEV occupations are transferable in the context of EV production. In this regard, the report did not observe any notable skill gaps for workers transitioning from ICEV to EV manufacturing.

However, we identified several important gaps in knowledge. Some of these gaps pertain to net-new types of knowledge about electric vehicles, electricity and EV batteries. Other gaps can be labelled as partial as they are knowledge that ICEV workers already have but need to update to work in EV manufacturing. Partial gaps apply to both vehicle and production components.

Some specialized roles related to EV batteries, electric motors and power electronics are unique to EVs. Some of these occupations are likely to be filled externally given that the highly technical expertise needed does not currently exist in ICEV production (e.g., chemists and chemical engineers).

A certain number of occupations are common to both ICEV and EV production. While the skills associated with these positions are transferable, knowledge gaps will need to be addressed by providing ICEV workers the right training and reskilling opportunities. To that effect, OVIN published a Reskilling Training Framework to support employers in transitioning their workforces to EV production by closing the gaps highlighted in this report so that no auto worker is left behind.

Methodology and Data Limitations

This report uses occupations and jobs as its main units of analysis to assess the auto manufacturing sector.

OEM job postings and data from the Automotive Industries Association of Canada (AIA Canada) were utilized to find positions involved in the production of ICEVs. Each job was assigned an occupation at the five-digit level (known as an NOC unit group) using the Government of Canada NOC search tool (2021 version)[20]. For each occupation, we identified the ten most in-demand skills and knowledge in online job postings across industries between January 2018 (oldest data publicly available) and July 2024. This was done by leveraging the Canadian Job Trends Dashboard developed by the Labour Market Information Council (LMIC)[21].

We identified positions in EV manufacturing using EVcareers.ca, a platform developed by economic development and training organizations in the Windsor region (i.e., Invest WindsorEssex, Workforce WindsorEssex, WEtech Alliance, the University of Windsor and St. Clair College)[22]. The platform provides an extensive list of jobs in the EV sector. Each job was assigned a five-digit occupation. The skills and knowledge associated with each occupation were then identified.

Taken together, the ICEV and EV data was used to contrast and compare occupations and jobs as well as the skills and knowledge requirements. The evaluation matrix below helped uncover skills and knowledge that are either lacking (gaps) or transferable in the context of the transition from ICEV to EV manufacturing.

Evaluation Matrix

		Occupation	
		Same for ICEV and EV	**Different for ICEV and EV**
Skill/ Knowledge	Same for ICEV and EV	Transferable	Transferable
	Different for ICEV and EV	Gap	Gap

In order to assess whether a skill is transferable, we developed a matrix to identify matches between ICEV and EV manufacturing.

Matrix to Match Skill Requirements

Skill Required in ICEV Manufacturing	Equivalent Skill in EV Manufacturing	
Analytical skills	• Data analysis	• Research
Communication skills	• Communication skills • Public speaking	• Oral communication • Written communication
Customer service	• Support skills	
Decision-making	• Decision-making	
Interpersonal skills	• Interpersonal skills	• Relationships
Leadership	• Leadership	
Organizational skills	• Organization skills	• Time management
Planning	• Planning	• Coordinating
Problem solving	• Problem solving	
Project management	• Project management	• Management skills
Supervisory skills	• Management skills	
Teamwork	• Teamwork	• Support skills
Time management	• Time management	• Organizational skills
Trouble shooting	• Problem solving	
Written communication	• Written communication	• Communication skills

Data Limitations

This report relied on secondary data to identify jobs and occupations in ICEV and EV production. As a result, the list of occupations as well as skills and knowledge needed for each manufacturing process is not exhaustive. This limited our ability to systematically identify all occupations that are common to both ICEV and EV production.

Endnotes

[1] Statistics Canada. (2024). Table 14-10-0202-01 Employment by industry, annual. Retrieved August 20 from *https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1410020201*

[2] Government of Ontario. (2024). Building a Better Ontario: 2024 Ontario Budget. *https://budget.ontario.ca/2024/pdf/2024-ontario-budget-en.pdf*

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[4] Government of Canada. (2023, June 2). Taxonomy. *https://noc.esdc.gc.ca/SkillsTaxonomy/TheTaxonomy*

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[7] See Government of Ontario. (2022, September 19). Ontario's Critical Minerals Strategy 2022–2027: Unlocking potential to drive economic recovery and prosperity. *https://www.ontario.ca/page/ontarios-critical-minerals-strategy-2022-2027-unlocking-potential-drive-economic-recovery-prosperity* and Government of Canada. (2023, September 12). The Canadian Critical Minerals Strategy. *https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html*

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[9] The three projects that were used to identify job postings are the plants in St. Thomas (Volkswagen) Windsor (Stellantis and LG Energy Solution) and Saint-Basile-le-Grand (Northvolt). Some postings from a Northvolt sister plant in Sweden were also used to complement the data.

[10] Based on data from Labour Market Information Council. (2024). Canadian Job Trends Dashboard. Retrieved August 21 from *https://lmic-cimt.ca/data-dashboards/canadian-job-trends-dashboard/*

[11] Knowledge types tied for a position are awarded the same ranking. In this context, two knowledge types are tied for second place, which means the following one gets ranked fourth.

[12] Cotterman, T., Fuchs, E. R., Whitefoot, K. S., & Combemale, C. (2024). The transition to electrified vehicles: Evaluating the labor demand of manufacturing conventional versus battery electric vehicle powertrains. Energy Policy, 188, *https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4128130*

[13] Ibid.

[14] Based on data from Careers WindsorEssex. (2024). Explore EV Occupations. Retrieved August 21 from *https://www.evcareers.ca/explore-occupations/*

[15] Skills tied for a position are awarded the same ranking. In this context, two skills are tied for fifth place, which means the following one gets ranked seventh.

[16] Knowledge types tied for a position are awarded the same ranking. In this context, two knowledge types are tied for second place, which means the following one gets ranked fourth.

[17] Government of Canada. (2023, June 2). 94200 – Motor vehicle assemblers, inspectors and testers. *https://noc.esdc.gc.ca/Structure/NocProfile?objectid=ZTrjWEItNLWUTzKkxV%2BSV7iS7r8hbeQxFnxOYjkPuZQ%3D*

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Appendix A List of Occupations in ICEV Manufacturing

Occupation	Occupation Code
Computer systems developers and programmers	21230
Construction millwrights and industrial mechanics	72400
Contractors and supervisors, machining, metal forming, shaping and erecting trades and related occupations	72010
Electrical and electronics engineering technologists and technicians	22310
Electrical and electronics engineers	21310
Engineering managers	20010
Heavy equipment operators	73400
Industrial and manufacturing engineers	21321
Industrial designers	22211
Industrial painters, coaters and metal finishing process operators	94213
Machine operators of other metal products	94107
Machining tool operators	94106
Machinists and machining and tooling inspectors	72100

Occupation	Occupation Code
Manufacturing managers	90010
Mechanical engineering technologists and technicians	22301
Mechanical engineers	21301
Metalworking and forging machine operators	94105
Motor vehicle assemblers, inspectors and testers	94200
Other technical trades and related occupations	72999
Production and transportation logistics coordinators	13201
Public and environmental health and safety professionals	21120
Software engineers and designers	21231
Supervisors, motor vehicle assembling	92020
Supervisors, supply chain, tracking, and scheduling coordination occupations	12013
Tool and die makers	72101
Welders and related machine operators	72106

Appendix B List of Occupations in EV Manufacturing

Occupation	Occupation Code
Assemblers and inspectors, electrical appliance, apparatus and equipment manufacturing	94202
Chemical engineers	21320
Chemical technologists and technicians	22100
Chemists	21101
Contractors and supervisors, machining, metal forming, shaping and erecting trades and related occupations	72010
Data scientists	21211
Drafting technologists and technicians	21310
Electrical and electronics engineering technologists and technicians	22310
Electrical and electronics engineers	21310
Electricians (except industrial and power system)	72200
Electronics assemblers, fabricators, inspectors and testers	94201
Engineering managers	20010
Industrial and manufacturing engineers	21321
Industrial engineering and manufacturing technologists and technicians	21321
Machining tool operators	94106
Machinists and machining and tooling inspectors	72100

Occupation	Occupation Code
Manufacturing managers	90010
Material handlers	75101
Mechanical assemblers and inspectors	94204
Mechanical engineering technologists and technicians	22301
Mechanical engineers	21301
Metallurgical and materials engineers	21322
Motor vehicle assemblers, inspectors and testers	94200
Occupational health and safety specialists	22232
Other professional occupations in physical sciences	21109
Procurement and purchasing agents and officers	12102
Production and transportation logistics coordinators	13201
Purchasing and inventory control workers	14403
Purchasing managers	10012
Software developers and programmers	21232
Statistical officers and related research support occupations	12113
Supervisors, motor vehicle assembling	92020

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Where Next Happens

The Transition to EV Manufacturing:

A Reskilling Training Framework

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Contents

Executive Summary

The automotive industry is in the midst of a multi-faceted transformation. Electric Vehicles (EVs) are due to supplant Internal Combustion Engine Vehicles (ICEVs) as the primary form of new vehicles in the next decade in Canada and the USA. Today's new vehicles, increasingly defined by software, are packed with digital technology and innovative features, and manufacturers must adjust to these changes too. Simultaneously, manufacturing itself is being transformed through digital transformation and increased automation. On the horizon, we can expect increased application of Artificial Intelligence and progress toward autonomous driving to continue to drive change in the industry.

Ontario's automotive sector is preparing for this future, and part of that preparation involves equipping our workforce with the knowledge and skills required to enable our manufacturers to transition their plants to EV production and to maintain their leadership position as the industry progresses through this transformation.

Ontario's experienced automotive workers are key enablers of our industry's success and our province's prosperity. Retaining their experience and skills as we transition to EV production will require that many of them reskill to some degree, augmenting their knowledge and experience in ICEV production with the additional knowledge they will need to manufacture EVs.

Reskilling our automotive workforce will require the participation of an ecosystem that includes employers such as automotive OEMs and educational institutions such as universities and colleges, supported by the government of Ontario along with other levels of government.

We find that full-time courses of study may not easily meet the needs of reskilling workers, who are typically pursuing learning while employed. Micro-credentials, an emerging model that offers higher education in a more granular format, are a better fit, especially when they are industry-informed and tailored to meet specific needs. Technology-mediated delivery modes that allow students to work at varying paces from locations that are convenient for them will also help workers fit reskilling education into their busy lives.

Reskilling will be a journey for employers and workers, and it may follow a number of pathways. We present pathways for ten occupations that are common to ICEV and EV production. We identify specific resources that employers and workers may use to begin the work of reskilling and address EV knowledge gaps. We also suggest ways to integrate the learning into comprehensive reskilling journeys.

The reskilling journey will unfold on many dimensions, and it is only beginning. We explore how employers can support reskilling, and consider how to enable to continuous improvement across the ecosystem over time.

This report seeks to provide a foundation upon which major ecosystem players can build programs that meet their specific needs and leverage their strengths to maximum effect. We close with a number of recommendations for employers such automotive OEMs, education and training providers, and government.

Introduction

The transition from internal combustion engine vehicles (ICEVs) to electric vehicles (EVs) is well underway worldwide; Ontario, long a significant player in automotive manufacturing, is positioned to play a key role in the industry's electrified future.

Over the coming years, auto manufacturers operating in Ontario will look to ramp up production of EVs. The EV transition will open many new opportunities for workers in Ontario.

EV manufacturing plants will be staffed by workers with a variety of backgrounds. Some will be entering the workforce, ideally armed with diplomas and degrees that anticipate the EV transition's needs. Others will have experience in manufacturing from other industries. Individuals with experience in automotive manufacturing may come from automotive parts manufacturers and suppliers or have experience working for original equipment manufacturers (OEMs) in the manufacturing of ICEVs.

This report is most concerned with automotive workers with experience in ICEV manufacturing. Their experience lies in a production segment that may be sunsetting and many will need to reskill lest they be displaced in the coming years. Moreover, the growing EV industry is already facing a shortage of skilled workers[1]. If Ontario's automotive industry is to retain the skilled workforce that has enabled its success in the ICEV space, we must support the reskilling of experienced ICEV workers to staff EV manufacturing.

The work of ensuring that Ontario's automotive industry can retain the skilled workers required to enable its transition to EVs will require many hands. OEM firms will be key contributors, playing many roles in supporting workers in their reskilling journeys. The broader automotive sector must also participate, especially where parts required for EVs differ from those used in ICEVs, and where change is needed to meet increasing demand for EV service, maintenance, and infrastructure. Education and training institutions will find new opportunities as the demand for reskilling mounts, and—as this report will discuss—should consider how they may need to adapt to meet the specific needs of reskilling automotive workers. Governments will be called upon to support the process from many angles. This report offers important insight for these audiences and other interested parties.

Multi-Faceted Transitions

To an extent, reskilling requires anticipating the future of the auto industry at a time when it is simultaneously undergoing multiple transitions. The shift from ICEVs to EVs is occurring in parallel with increasing automation in manufacturing, the shift to software-defined vehicles[2], progress toward autonomous driving, the migration toward Industry 4.0[3] and the related rise of AI use in industry, among other innovation trends. Education and training are also undergoing change: new modes of delivery are growing in popularity, and educational credentials are evolving toward increased granularity and flexibility, as evidenced by the proliferation of remote learning options and the rise of micro-credentials. In order to accommodate future change resulting from these transitions, an EV reskilling framework must be flexible and adaptive, and designed to leverage ongoing innovation in training and education.

What You Will Find in this Report

This report provides a framework for reskilling workers with ICEV manufacturing experience. It begins by charting the skills and knowledge landscape in the EV manufacturing sector. It identifies knowledge gaps of ICEV workers that will need to be addressed to enable them to transition to EV production.

This is followed by an exploration of the EV training ecosystem that profiles government-supported reskilling initiatives, considers the ways in which credentials map to reskilling needs and profiles the wide array of training and education options available to support reskilling. These options range from universities and colleges to training provided by OEMs and manufacturing equipment providers to emerging models such as micro-credential collaborations. The latter allows higher learning institutions such as colleges to meet the specific needs of corporations wishing to enable reskilling of workers. This section also considers a variety of training methods and how these various methods might best be deployed to efficiently and equitably support the ICEV workforce in reskilling for the EV transition. The roles employers can play in actively supporting reskilling of their workforces are also discussed.

The report then outlines reskilling pathways to address the knowledge gaps identified in the first section. Reskilling journeys that consider the type of gaps and knowledge required, potential providers, categories of trainings, and sequencing are presented.

Our analysis then considers how progress can be monitored and assessed against key performance indicators (KPIs), and how to enable continuous improvement of the reskilling framework and pathways so that the system improves over time while keeping pace with change. We also highlight important equity, diversity and inclusion (EDI) considerations that should guide reskilling practices in the industry.

We also consider the human factors of the transition: how workers' mental health and well-being may be impacted by being swept along in this global transition, and how the many stakeholders in the ecosystem can best support workers along their journeys.

The report finishes by summarizing our recommendations in a single frame, affording readers a means of easy access to the key considerations with respect to reskilling.

1. The Skills and Knowledge Landscape in the EV Manufacturing Sector

A wide array of positions is needed to manufacture electric vehicles. The EVcareers.ca platform identifies 51 different job titles, which can be grouped under 32 occupations under the 2021 National Occupational Classification (NOC) system. Skills and knowledge requirements associated with these roles are extensive. We identified in total nearly 150 different skills and knowledge. Over three quarters of them are knowledge.

Some EV occupations already exist in ICEV production. Workers in these positions have highly transferable skills. However, they face knowledge gaps as EVs have distinct components and work differently. Some gaps are net-new types of knowledge about electric vehicles, electricity and EV batteries. Other gaps are partial and relate to knowledge that ICEV workers possess that must be updated to reflect EV-related differences. This applies to both vehicle and production components. Some aspects of ICEV knowledge are not applicable to EVs, and will eventually become obsolete. For instance, electric vehicles do not have fuel tanks or exhaust systems, which means no one on the assembly line will need to know how to install these components.

Some roles related to EV batteries, electric motors and power electronics are unique to EV production. They do not currently exist in ICEV manufacturing. Given their highly scientific and technical nature, reskilling is not adequate to fill the knowledge gaps associated with these occupations (e.g., chemists and chemical engineers). In this regard, employers will have to hire externally for these positions.

The table below identifies the net-new and partial gaps that apply to occupations that are common to ICEV and EV production.

Type of Gap	Gap	Occupation common to ICEV and EV production											
		Electrical and electronics engineering technologists and technicians	Electrical and electronics engineers	Electricians (except industrial and power system)	Engineering managers	Industrial and manufacturing engineers	Machining tool operators	Machinists and machining and tooling inspectors	Manufacturing managers	Mechanical engineering technologists and technicians	Mechanical engineers	Motor vehicle assemblers, inspectors and testers	Production and transportation logistics coordinators
Net-new gap	Battery pack		X						X		X		
	Battery management	X											
	Computer engineering	X											
	Electrical engineering					X			X	X	X		
	Electricity											X	
	Electric motor	X					X	X					
	Electric vehicle	X	X						X		X		
	Mechanical engineering		X										
Partial gap	Axles						X	X					
	Chassis									X			
	Electronics	X	X						X		X		
	Integration		X	X		X	X	X	X	X	X		
	Installation			X									
	Powertrain		X			X	X	X	X		X		
	Propulsion		X			X			X		X		
	Subsystems						X	X					
	Transmission system		X				X	X					
	Voltage/high voltage	X	X										

2. The EV Training Ecosystem

The training ecosystem in Ontario consists of a wide array of organizations. Formal education institutions such as universities and colleges across the province already offer full-time degree and diploma programs that prepare students for a future in the EV industry. These education providers are supplemented by a host of training providers—some based in Ontario, and others operating in other parts of Canada and around the world, offering digitally delivered learning that can be accessed from anywhere.

The Government of Ontario has taken an active role in ensuring the automotive sector has access to a workforce with the necessary skills, and has launched several initiatives in support of this goal. In 2020, the province invested in a range of educational programs intended to prepare experienced workers and college and university students for careers in the automotive and advanced manufacturing sectors[4]. OVIN, launched in 2021, published a Talent Strategy & Roadmap for Ontario's Automotive and Mobility Sector to ensure Ontario has access to the skilled, talented, and diverse workforce required to remain globally competitive[5]. Launched in 2023, OVIN's Regional Future Workforce (RFW) program provides funding to innovative projects focused on connecting the next generation of workers with the auto sector[6]. OVIN's Content Partnerships Program (CPP) helps post-secondary institutions develop micro-credentials for automotive workers to upskill[7]. This content is available on OVIN Learn, OVIN's learning hub for the automotive and mobility sector which recently went live[8].

The Government of Canada has contributed as well through programs such as Quick Train Canada[9], supported through the Sectoral Workforce Solutions Program[10], and the Upskill Canada platform, where Palette Skills offers courses in advanced manufacturing[11].

Experienced workers looking to reskill are often still employed. Reskilling workers are likely to be over the age of 25, and in either the Establishment or Maintenance phases of their careers[12]. As life progresses, responsibilities outside of work tend to increase, making it more difficult to dedicate two or more years to full-time study in pursuit of a new diploma or degree.

The needs of experienced workers are more likely to be met through innovative approaches such as micro-credentials—short training programs that may be tailored to meet labour market needs[13]. Micro-credentials can be obtained through brief courses of study, and are generally intended to be "stackable", allowing learners who pursue many micro-credentials to build up to a macro-credential over time[14]. Stackability is an attribute that may prove highly valuable in the reskilling context, opening the door to workers pursuing varied learning pathways that can account for their prior qualifications and experience and be tailored to meet the specific needs of various jobs in the EV sector.

Reskilling Needs to Be Flexible

2.1. Reskilling Providers in Ontario

Workers in Ontario seeking to reskill may choose from a variety of providers. We profile a handful of options here, selected to provide a representative overview of the range of options.

2.1.1. Post-Secondary Institutions

Universities and colleges across the province offer degree and diploma programs that prepare students for employment in the EV sector. University degrees and college diplomas remain the gold standard in credentials, and are required or preferred in order to qualify for many roles in the EV sector. Though many institutions in Ontario offer these programs, they universally require one or more years of full-time study.

UNIVERSITIES

The EV industry already exhibits strong demand for engineers[15], and all such positions require an undergraduate degree in engineering at a minimum. Workers wishing to qualify for these roles typically must pursue a 4 year full-time degree. Part-time studies are offered at University of Toronto, but part-time students must attend courses in-person during the day[16], so many full-time employed workers would have difficulty accessing the program despite it being offered on a part-time basis.

Many universities offer continuing education, and some offer micro-credentials. Few engineering courses are available in these modes, but there are exceptions such as those offered under the Licensing International Engineers into the Profession (LIEP) Program[17]. In response to legislation introduced in 2021, Ontario became the first jurisdiction in Canada to drop the requirement for Canadian experience to qualify for licensing as an engineer[18]. LIEP was subsequently rolled out to help internationally educated engineers qualify for licensing. University of Toronto offers a series of online courses that can be applied towards the LIEP certificate, and these courses are also intended to support ongoing professional development for engineers and other professionals who possess the required knowledge to take the courses.

For example, Power Systems & Machines[19] may be useful to engineers wishing to refresh their knowledge with a view to moving into EV manufacturing. It is possible that workers with advanced knowledge who lack a degree might pursue these courses—they have no prerequisite, but do specify the knowledge that enrollees should possess.

Looking to the future, these LIEP courses might serve as a proof of concept for offering engineering education online in formats that align with reskilling needs. Our research has found few existing options for those wishing to reskill or upskill towards engineering or engineering technology while continuing to work.

COLLEGES

Colleges in Ontario offer a range of credentials:

- Undergraduate degrees: 4 years full-time
- Ontario College Advanced Diploma programs: 3 years full-time
- Ontario College Diploma: 2 years full-time
- Ontario College Certificate: 1 year full-time or equivalent part-time
- Ontario College Graduate Certificate: 1 year full-time or equivalent part-time, for students who have already completed other post-secondary studies
- Micro-credentials

Three-year programs that confer Ontario College Advanced Diplomas frequently include co-op terms. Some, such as Centennial College's Electrical Engineering Technology program, offer co-op and non-co-op versions. Others, such as that offered by Mohawk College, require co-op placement. Students who elect to pursue co-op programs must complete their co-op work experience hours in addition to the mandated course work.

Two-year Ontario College Diploma programs that prepare students for careers in the EV space can be found at many institutions. Many are focused on Engineering Technology or Technician studies, allowing students to specialize in a range of sub-disciplines such as electrical, electronics, mechanical, chemical and process, and software engineering. Examples include the Electrical Engineering Technician program at Niagara College and the Electromechanical Engineering Technician program offered by Sheridan College at its Brampton Campus. A full list of programs can be found online[20].

Case Study

St. Clair College's School of Skilled Trades offers a 2-year Electric Drive Vehicle Technician program that confers an Ontario College Diploma. The program includes a work placement program, and prepares students for employment in roles such as Electrical and Electronic Engineering Technician or Automotive Service Technician[21].

College Certificate programs may also offer appropriate preparation for EV careers, though they tend to be comparatively general and aimed at pre- or early-career students rather than at experienced workers, and few relevant programs offer options to study part-time. However, programs offering additional flexibility have emerged. College Certificate programs require 600 hours of course instruction. These hours can be completed in two full-time semesters, but might also be completed at a slower pace, as in the Electric Vehicle Technician program offered by George Brown College.

Case Study

George Brown College's School of Mechanical Engineering Technologies offers an Electric Vehicle Technician program that confers a George Brown College Certificate. The program consists of 14 modules that require the equivalent of 32 weeks of full-time study, but are delivered asynchronously and on-demand, allowing students to progress at their own pace[22].

Many of the most relevant micro-credentials are offered by colleges. Since many micro-credentials are conducted online, students need not be restricted to colleges near their homes or places of work. George Brown College's School of Distance Education offers six EV-relevant technician programs to students around the world. These technician micro-credentials can be pursued by individual students or can be packaged and delivered as corporate training. Each of the technician programs is marketed via a stand-alone website[23].

2.1.2. Professional development and training through third parties, including equipment providers

Some reskilling needs will be best met by third parties. In some cases, companies who supply software and equipment to EV manufacturers have developed training to accompany their products. These training programs do not follow a common pattern. Some, such as Siemens Mechatronics Systems Certification, are quite lengthy and are offered by a college or university in partnership with Siemens[24]. Others, such as trainings from MathWorks, are offered in brief courses delivered virtually, either synchronously or asynchronously[25].

Case Study

Festo Inc, an industrial automation firm that supplies automotive manufacturers, has created the Festo Learning Experience (Festo LX), an online portal that offers a customized learning experience for teachers and learners. Festo LX aims to make it easier for Festo's industrial clients such as automotive OEMs to train and educate their workforces. Course material covers EV-related topics such as mechatronics and electric vehicle and battery manufacturing[26].

2.1.3. Emerging collaborative models

Micro-credentials created and delivered through partnerships represent a growing area. We have already mentioned Siemens Mechatronics Certification, a partnership between a manufacturing equipment firm and colleges and universities around the world. Another example can be found through a partnership between: ACCES employment, a community-based workforce development organization and registered charity that helps workers who face barriers gain employment in the Canadian job market; Palette Skills, a national non-profit that cultivates talent for innovative companies; and Humber College. This partnership has created a free, industry-informed program aimed at mid-career workers seeking work in advanced manufacturing[27]. The program consists of five micro-credentials that "stack" into a certificate in Advanced Manufacturing[28].

Partnerships such as this represent a promising model for reskilling: leveraging industry's knowledge of its needs in combination with the pedagogical expertise found at higher education institutions, and delivering the learning through flexible micro-credentials. This should allow growing industries such as EV manufacturing to connect reskilling workers to learning that is highly targeted, flexible enough to be completed while working, of high quality, and confers credentials that will be widely recognized. As we will discuss in greater detail when considering change management, it is important that the benefit of taking on the learning is clear to workers going through reskilling; credentials that meet employer needs while signaling value to the wider world will contribute to the perceived benefit.

2.2. The Role of the Employer in Reskilling

If they wish to retain the skilled workforces that have enabled their success to date, automotive manufacturers should take an active role in enabling reskilling.

2.2.1. Internal Corporate Training

Little data is available on the current prevalence of in-house corporate training programs that help workers reskill for EV manufacturing, but larger employers who wish to transition many workers from ICEV to EV may find it more efficient to invest in developing in-house training programs. Internal employee-specific models offer some distinct advantages, such as:

- They may be tailored to the specific needs of the employer and employees
- They can be informed by detailed knowledge of the specific processes and equipment in use at the employer offering the training
- Workers all receive the same training, ensuring a common language and understanding of the material
- Monitoring uptake and progress will be easier since the employer will have full control of the program

2.2.2. Peer-to-Peer Training

Peer-to-peer (P2P) training is a core method employed by the OEM manufacturer we spoke with while preparing this study. They reported using a variety of approaches ranging from casual job shadowing to formalized programs where expert, highly experienced employees are trained to provide on-the-job education (train the trainer) and deliver training to other employees that leverages learning material provided by equipment suppliers and other relevant content, contextualized by the applied knowledge the trainers possess by virtue of their expertise.

P2P training has the advantage of leveraging the knowledge resident in the organization, allowing the employer to retain and spread the granular understandings that experienced workers develop over time. In general, whereas formal education must be general so that students can use their learning to pursue a range of career paths, less formal on-the-go training may be highly specific to the distinct needs encountered on the shop floor.

One disadvantage of the P2P model is that it will not naturally keep pace with innovation in tooling and technology. Whereas formal learning providers must stay on top of how the industry is changing so that their students will be prepared for the future, P2P learning is handed down from experienced workers who may have gained their skills and knowledge in the pre-digital era.

Another disadvantage of P2P is that the knowledge it centres on is often less formally codified. When a worker trains another worker in the performance of a given task, there may be no record of the knowledge that was transferred. This can impact measurability, making competency assessment more difficult, limiting the scope for corporate Learning and Development (L&D) functions to increase efficiency or leverage training reusability to improve return on investment (ROI) for training.

2.2.3. Collaborating with Unions

Labour unions who represent auto workers, such as Unifor, offer courses to members. Though Unifor's website does not currently list any technical training, the union does offer courses in Health and Safety and Leadership Development[29]. These courses are not intended to support EV transition reskilling, but unions have shown strong interest in representing their members' interests in the EV transition and in ensuring that members have access to good automotive sector jobs in the future. As the transition progresses, unions may develop an interest in supporting reskilling for members.

2.2.4. Enabling Access to the Right Training

Employers are better positioned than workers to understand the skills and knowledge they need. They can use this understanding to identify appropriate training, support the creation of appropriate training where necessary, and develop a plan for workers to pursue that training. These steps are expanded upon in greater detail when we explore pathways to reskilling and training later in this report.

Employers should anticipate needing to invest in creating some portion of the training employees require to reskill. Much of what's needed for a comprehensive reskilling program can be assembled from pre-existing components—there is a vast amount of potentially relevant learning content available through post-secondary institutions, tooling and equipment manufacturers and suppliers, and other sources—but there will certainly be gaps that must be filled and substantial needs that are employer or plant-specific. These may be best covered by training programs developed and delivered by employers, leveraging partnerships and collaboration where merited. OEMs may differ in their needs and perspectives as to which aspects they prefer to handle internally and which they decide to source externally.

A robust approach should consider staged training using a range of formats and providers, ranging from institutions to corporate trainers to peer-based, integrated and monitored via a CW platform or equivalent.

2.2.5. Supporting Workers Who Are Reskilling

Workers who opt to reskill are investing time to ensure their talent is supported by the skills their employers need. If they are working while reskilling (as is likely), they may find they are under time pressure. Employers can play a supportive role to help reskilling workers along on their journeys. This might involve creating a working environment that values reskilling; measures might include making time available for workers to pursue training the employer values. It may also take the form of full or partial tuition subsidies, making it easier for workers to afford to reskill. Employers should consider programs such as the Canada-Ontario Job Grant, which covers half of training costs (up to $10,000 per person) for employers investing in training their workforce using eligible third-party trainers[30]. When employers make it clear that they value reskilling, they help create a work environment that encourages workers to learn and grow, and thus keep pace with the changing needs of industry.

3. Training Delivery Formats and Modes

Reskilling training can be delivered through a variety of formats ranging from the classroom to the shop floor to over the internet. Emerging approaches have begun to leverage digital innovations such as Industry 4.0[31] and virtual and augmented realities (VR/AR).

3.1. Blended Learning

In general, reskilling education is likely to employ a blended approach[32]. Courses of instruction can be offered via a mix of classroom (in-person or virtual) and non-classroom activities. Course developers can pick from a range of formats, using a mix of synchronous and asynchronous modes.

3.2. Synchronous vs Asynchronous

Learning can be delivered asynchronously or synchronously[33]. The classic classroom approach is synchronous: all students and the instructor are present at the same time. This offers some benefit in that discussion is easier and more natural. It also provides a set schedule for students.

Asynchronous learning, by contrast, is configured to allow students to proceed at their own pace, working at times that suit them. We have long used blends of both modes in learning: whereas classroom work in schools tends to be synchronous, homework is asynchronous.

With the rise of digital technologies and virtual learning, educators have been able to offer more value in the asynchronous mode. Learning Management Systems (LMS) make it possible to deliver classroom learning to students working at their own pace. Lectures, which have typically required in-person attendance, may now be delivered via pre-recorded video that students can view when convenient for them. Discussion which would have taken place in the classroom can now unfold over time using digital messaging threads. The knowledge shared accumulates on the platform, making it easier for students to access than traditional synchronous classroom learning, which required students to be present to take their own notes and arrange accommodations for missed classes or other scheduling constraints.

3.3. Range of Formats

Different learning objectives are best served by different formats.

3.3.1. Classroom

A classroom setting may be most appropriate for conceptual material that lends itself to lectures and group discussion. Classrooms do not need to be in-person; virtual classrooms are common today, and may play a key role in EV reskilling. The use of virtual classrooms allows learning providers to include students from multiple locations in a single class, and allows students to attend from a convenient location and save time that would have been spent commuting to in-person classes.

3.3.2. Experiential

Learners working to add applied skills may be better served by experiential formats such as job shadowing. Experiential learning that is hands-on is particularly well-suited to reskilling. A 2021 BCG study found that 65 per cent of adults prefer to learn on the job[34].

Many learning activities that would help withreskilling qualify as experiential:

- Work-integrated learning such as co-op
- Shop floor demonstrations
- Peer-to-peer training
- Job shadowing
- Mentorship

3.3.3. Recorded

Video has become a mainstay of training and education in recent years. Recorded training videos will form part of the mix. Some may be provided by equipment suppliers, such as those found on Festo LX, as discussed above.

3.3.4. Emerging Technologies: Extended Reality

AR and VR are already seeing increased use in training for industrial tasks[35]. VR and AR are frequently discussed in the same breath, but the two technologies differ significantly in user experience and in the opportunities they offer to educational designers. VR places the user in a fully-virtual environment, whereas AR overlays digital graphics on top of real-world objects. The picture is complicated by evolving terminology: experts now speak of mixed reality (MR), in which real-time video of the external environment is mixed into VR, and extended reality (XR), an umbrella term for AR, MR and VR[36].

From the vantage of 2024, when these technologies are still quite new, it is difficult to say which formats will be best for reskilling. Some studies have found that AR yields slightly better results, especially for older workers[35,37], yet some manufacturers have reported excellent results using VR[38].

3.3.5. Looking Forward

As automotive manufacturing continues to digitize, closing in on what thought leaders term Industry 4.0[3], it will become easier to use these XR technologies in more aspects of training. When manufacturers have full digital replicas ("digital twins") of their entire shop floors, and of all their equipment and vehicles, AR might be used to provide an instructional overlay to assist workers who are learning on the job.

4. Bringing it Together

In order to leverage the ecosystem, reskilling efforts will require means to integrate the various aspects described here into programs that can support journeys from today's ICEV current state to the EV workforce of tomorrow and facilitate the ongoing learning required to keep pace with continuing innovation in manufacturing and automotive technology. We profile three different integrating concepts here.

4.1. Staged Training Models

According to the OEM interviewed for this report and a recent study assessing the changing needs of Canada's manufacturing workforce, the ability to work independently is a key need for the automotive sector[39].

A 2023 study focusing on training workers for the needs of tomorrow explored the challenges of training for independent performance of routine and non-routine tasks, and proposed a staged approach that harnessed corporate training and on-the-go training to supplement learners' foundational institutional training[40]. The study focused on offshore oil platform workers as an example, but the research and associated insights are applicable to other sectors such as auto manufacturing.

As the table on the next page shows, the authors of the study split training into three stages: general, onboarding, and on-the-go. Stage 1 general training is delivered by institutions, often prior to hiring. In the context of Ontario automotive manufacturing, institutions might include universities, colleges, and skilled trades programs. Once a worker has been paired with a role, the second stage, onboarding learning, begins. Onboarding workers learn about the specifics of the work environment, its equipment, the company culture, and the expectations and details associated with their role. This training may be delivered via internal corporate training. Once the employee begins work, their learning continues through stage 3, which offers on-the-go training to support the employee on an as-needed basis, providing detailed context-sensitive learning when it is needed for direct application, and thus most likely to be retained. The authors of this study proposed gamifying the training in phase 3, and using digital systems to deliver material developed by internal corporate training specialists[40].

Staged Competency Model

Source: Image from Longo, F., Padovano, A., De Felice, F., Petrillo, A., & Elbasheer, M. (2023). From "prepare for the unknown" to "train for what's coming": A digital twin-driven and cognitive training approach for the workforce of the future in smart factories. Journal of Industrial Information Integration, 32, 100437. https://doi.org/10.1016/j.jii.2023.100437

4.2. Connected Workforce (CW)

Sometimes referred to as Connected Worker Solutions, CW describes a form of digital transformation for manufacturing, encompassing a range of tools and technologies and platforms. Digital devices such as AR/VR glasses, hand-helds (tablets, phones), and wearables are connected via collaboration platforms that provide a digital connection layer overlaying the human and physical resources of factories. CW technologies enable context-sensitive information retrieval and storage that maps to the factory environment at a granular level. In a learning and skills context, they may be used for tasks such as capturing and scaling rare or expert skills, delivering work instructions and standard operating procedures at the location and time when they are needed, and in-context micro-training[41]. CW might be used to augment or perhaps eventually replace the peer-to-peer micro-training typical on shop floors today, helping employers formalize and standardize training. CW platforms also support assessment of learning (e.g. through exams and quizzes), and may also be used to identify risks and address gaps in employee learning, and to support on-the-go learning to enable independent work.

Canada-based Poka, a CW platform with a learning management component, has been used by Bosch Automotive to improve communication and track skills development[42]. Poka has also been used to facilitate experienced workers creating a skills database for worker roles and entire factories[43]. There are many other options for CW platforms and digital systems that help organize and monitor skills development in manufacturing.

4.3. Micro-Credentials and Open Badging

The Government of Ontario has been working to encourage the expansion of micro-credentials in the province, and has piloted a virtual passport that learners can use to track and share provincially certified micro-credentials[44]. The stackability of micro-credentials might also be leveraged through the use of an "open badge" format[45]. One example of a Canadian platform can be found in CanCred. We also have Canadian examples of open digital badges, such as CanCred Factory[46].

Many micro-credentials are already blockchain-ready. They are intended to be stackable. An open badge system can help make it easier to stack them to build up to recognized macro-credentials that EV employers can have confidence in.

In conjunction with the work the Ministry of Colleges and Universities has sponsored to foster quality assurance for micro-credentials in Ontario[14], a passport or open badge system might equate to a universal digital transcript that could record and attest to the micro-credential courses completed by students, facilitating ongoing learning for workers reskilling for the EV transition and the other technology transitions unfolding in the automotive industry, as well as whatever lies around the corner.

5. Pathways to Reskilling and Training

EV manufacturing in Ontario is only beginning. This study strives to meet the needs some employers are facing today and to anticipate future growth in volume and diversity of needs as the EV transition progresses.

As discussed above, courses of full-time study lasting one or more years are not likely to meet the needs of most workers looking to reskill. We anticipate that the workers who are the focus of this study may be employed while reskilling, and may also have other responsibilities and constraints that obviate returning to school full time for a prolonged period of time.

We have elected to focus on using micro-credentials as the core components of the pathways described in this report. Stackable micro-credentials present an ideal solution for addressing gaps in ICEV workers' foundational knowledge as they prepare to transition to EV production.

Micro-credentials also fit some of the needs of employers. While employers could create custom internal training to deliver foundational EV knowledge, training courses that do not confer credentials valued in the broader industry may be less appealing to workers from a change management perspective, and employers will already need to create training to meet more specific needs (i.e. onboarding and on-the-go learning in the staged model described above), so leveraging micro-credentials may reduce overall investment and the time required to develop a comprehensive reskilling program for all candidates. Employers seeking to enable access to foundational EV knowledge for reskilling employees may wish to incorporate micro-credentials from various institutions into employee reskilling journeys, and to use the pathways presented here to help identify gaps they wish to fill by investing in training creation or customization. Where there are gaps in what is available to meet foundational needs, new training underwritten by employers might take the form of industry-informed micro-credentials developed through partnerships with educational institutions.

Ontario has most of the components required for an effective and robust EV manufacturing reskilling ecosystem:

- Excellent learning institutions that offer courses that cover the required knowledge
- A micro-credential certification model and emerging quality assurance program
- Automotive manufacturers creating demand for EV manufacturing skills and knowledge
- Experienced automotive workers who make good candidates for reskilling for EV manufacturing roles

However, with some notable exceptions, the knowledge needed to fill the gaps defined in this report is not yet available from Ontario-based institutions in micro-credential formats. Many of the courses listed here are offered in other countries. Learning institutions in Ontario offer similar courses, but they tend to offer them only to full-time students in degree and diploma programs.

Micro-credentials are best suited to covering foundational knowledge, so can only represent a partial solution. Employers should also anticipate needing to invest in training to meet specific needs. It is unlikely that existing micro-credentials will cover specific machinery or software in use at a plant. The foundation gained through micro-credentials must be supplemented by targeted training that is informed by detailed knowledge of the specific roles and tasks workers will perform, and the equipment they will use. Learning content that meets these needs must be defined by the employer, and may be best delivered by the employer as onboarding and on-the-go training. Employers might also consider partnering with post-secondary institutions to develop custom courses that are only offered to their employees. Post-secondary institutions have shown interest in partnerships on this nature to deliver EV-related training[47].

5.1. Reskilling Journey for Employers

The pathways outlined here are intended to be flexible enough to accommodate growth and change in the availability of courses and credentials. We strive to propose options that employers and workers can begin using today to meet immediate needs, and to also suggest how the industry can work with the rest of the ecosystem to develop options that are Ontario-based and industry-informed, tailored to more readily meet the specific needs of Ontario’s automotive manufacturers and workers, and to evolve in response to anticipated innovation and change as the EV transition progresses.

Change Management is Key to the Success of Reskilling

Transitioning workers from ICEV to EV manufacturing must be seen through the lens of change management. It will not be enough for employers to simply introduce reskilling pathways—they must be prepared to support workers through this transition. A 2023 article in Harvard Business Review (HBR) suggested a number of ways in which change management can enable reskilling[48].

BUILD IT INTO MANAGEMENT INCENTIVES

Middle managers can sometimes resist reskilling. They may be concerned that workers will lose focus on their existing work while focused on reskilling-related training, or they may be concerned that they will lose their workers once they have reskilled. One way to counter this tendency is to make management explicitly responsible for encouraging employees to enroll in and complete training modules.

CONNECT WITH AND INVOLVE EMPLOYEES

Above all, treat employees as partners. Engage with them to help them understand why reskilling is needed and how it will benefit them. When employees are made aware of the roles they can qualify for if they do successfully reskill, they may more open to undertaking the work of reskilling. Managers should clearly describe future opportunities and the skills required in advance of rolling out reskilling programs, and should encourage workers to enroll[48].

5.2. Reskilling Journeys and Pathways

In this section, we present journeys for each occupation identified in Phase 1 that has knowledge gaps associated with transitioning from ICEV to EV manufacturing. The details are conveyed in tables that can be used to identify currently available learning options, and may also be used by employers wishing to develop—whether independently or in collaboration with ecosystem partners—new reskilling opportunities for workers.

5.2.1. Steps Along the Journey

IDENTIFY APPROPRIATE TRAINING

1. The journey begins by identifying the occupation(s) for which the employer wishes to support reskilling.
2. For each occupation, a list of anticipated needs is provided.
3. The employer may consider conducting internal research to validate how well the anticipated needs listed here correspond to the needs as they understand them, and to use the research to develop a list of anticipated needs that better meets their specific requirements.
    a. Employers should consider which aspects they deem foundational, and which are best covered in later stages through onboarding and on-the-go training.
    b. Employers may wish to take an inventory of existing in-house learning content that could meet some needs.
4. For each anticipated need, courses are suggested in the short-term example column, and additional resources may also be listed.
5. The employer may…
    a. Find that the options presented here meet their needs, or…
    b. Have existing in-house learning content they can leverage, or…
    c. Use the information listed to identify other training opportunities. New micro-credentials are currently being developed in Ontario, and we expect this to continue over the coming years, or…
    d. Use the information listed to inform work to develop training options that meet their needs. For example, SAE offers corporate training, and may be a good partner; Ontario universities and colleges may also make good partners in the development of tailored training and education. In some cases, employers may wish to create custom training in order to retain full ownership of proprietary IP.
6. The employer should now have sufficient information to define a learning journey for their employees.

IDENTIFY CANDIDATES AND ENCOURAGE ENROLLMENT

7. The employer should take measures to encourage employees to reskill. Possible approaches are discussed above under The Role of the Employer.
8. The employer identifies candidates for reskilling, and notifies them that they have been selected.
9. The employer may wish to work with candidates to develop individual reskilling journeys that meet their specific needs.
    a. Where appropriate, the employer may wish to modify employee responsibilities to facilitate their reskilling.

ENROLLMENT AND LEARNING

10. In cases where the employer is actively supporting reskilling for employees, the employer may wish to track progress for workers as as the learning proceeds.
11. Workers begin to enroll, supported by the employer.
12. Reskilling workers pursue learning opportunities.

COMPLETION AND VALIDATION

13. Upon completion of each course of study, reskilling workers should receive some sort of credential.
14. Credentials are validated, and the employee's new knowledge is recorded.
15. Once employees have finished their journey, the employer should endeavour to offer them new positions in accordance with their new qualifications.
16. The employer should collect feedback and measure success as employees progress and upon completion.
    a. Based on feedback collected, the employer may wish to refine their process, the learning opportunities they recommend to employees, and the supports in place.
    b. The employer may wish to track progress and measure success for some time after the completion of the journeys to determine how well the reskilling program meets their needs.

5.2.2. Reskilling Journey by Occupation

Our research identified 14 occupations (NOC unit groups) that are common to both ICEV and EV manufacturing. Based on the data available, ten of these occupations have knowledge gaps that will need to be addressed to transition to EV manufacturing. As the industry progresses through the transitions described in the introduction, other gaps will likely emerge. The journeys here should provide a model upon which employers can base the foundations of their reskilling programs, customized as needed to fill gaps in foundational knowledge, and supplemented with custom training to meet plant and role-specific needs.

HOW TO READ THE TABLES

The tables below summarize the gaps described in Phase 1 by occupation, and relate them to education and training offerings and the terminology used to describe them.

Sequence

Journeys are sequenced to begin with overviews and more foundational knowledge, and then to progress to more detailed and/or specific learning objectives.

For each occupation, several gaps may be accorded the same sequence value. For example, for electrical and electronics engineering technologists and technicians, the journey begins with an EV overview (sequence 1), then covers safety (sequence 2), and then progresses to several more technical gaps which we presume may be covered in any order, and are thus are all accorded a sequence value of 3.

Gap and Type

These correspond to the findings from Phase 1.

Anticipated Need

In many cases, the knowledge gaps described do not translate easily to the information found in course descriptions. We have thus re-articulated each gap as an anticipated need that can be more readily used as a search term to identify suitable courses.

Pathway

Many gaps pertain to multiple occupations, and some gaps are best grouped together for the purposes of identifying appropriate training and education options. For example, all battery gaps are grouped into a battery pathway. Gaps that are related to powertrain—powertrain, propulsion, axles, transmission systems—are all grouped into a powertrain pathway.

Short-Term Example

For employers and workers with immediate needs, courses are presented for almost all gaps. Course titles and hyperlinks are listed. In cases where the specific needs are not yet clear, we have noted a need for additional information. We expect that employers will have access to a more detailed understanding of the gaps and will be better positioned to develop an anticipated need that can be filled.

Additional Resources

The short-term examples are bolstered by two columns of additional resources where additional options or examples were identified. Employers and workers should be able to use the resources listed to find the course best suited to the specific needs. Organizations interested in developing Ontario-based resources should be able to use the examples and links provided to develop an understanding of the courses available outside Ontario.

Electrical and Electronics Engineering Technologists and Technicians

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
1	Electric vehicles	Net-new	EV overview course	EV overview	CADD Centre Electric Vehicle Technology Overview	CADD Centre Executive Diploma in Electric Vehicle System Design and Analysis	
2	Voltage/high voltage	Partial	EV high voltage safety course	Electricity safety	Camosun College CEET 200V - EV High Voltage Safety and Systems Familiarization Micro-Credential	SAE Fundamentals of xEV, Safety, and PPE PD5322	SAE High Voltage Vehicle Safety Systems PD291808
3	Battery management	Net-new	Battery management systems course	Batteries	SAE Battery Management Systems PD772317	SAE EV Batteries Courses	
3	Computer engineering	Net-new	Computer engineering for EVs	Computer engineering for EVs	more information needed		
3	Electric motors	Net-new	Electric motors course	Electric motors	SAE Fundamentals and Applications of Electric Motors for Automotive Industries C1870		
3	Electronics	Partial	Electronics for EVs for engineering	Electronics	more information needed		

Electrical and Electronics Engineers

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
1	Electric vehicles	Net-new	EV overview for engineers	EV overview	CADD Centre Electric Vehicle Technology Overview	CADD Centre Executive Diploma in Electric Vehicle System Design and Analysis	
2	Voltage/high voltage	Partial	EV high voltage safety course	Electricity safety	Camosun College CEET 200V - EV High Voltage Safety and Systems Familiarization Micro-Credential	SAE Fundamentals of xEV, Safety, and PPE PD53220	SAE High Voltage Vehicle Safety Systems PD291808
3	Battery pack	Net-new	EV battery course	Batteries	SAE Introduction to Hybrid and Electric Vehicle Battery Systems C0626	SAE EV Batteries Courses	
3	Mechanical engineering	Net-new	EV Mechanical engineering	EV Mechanical engineering	more information needed		
3	Electronics	Partial	Electronics for EVs for engineering	Electronics	more information needed		
3	Integration	Partial	EV subsystems and integration	Mechatron-ics	Siemens Mechatronic Systems Certification Program Level 1 (University of Windsor)	Siemens Mechatronics Certification Program Levels 2 and 3	

Electrical and Electronics Engineers

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
3	Powertrain	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electric Vehicle Engineering Academy ACAD06
3	Propulsion (powertrain)	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electric Vehicle Engineering Academy ACAD06
3	Transmission systems	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electric Vehicle Engineering Academy ACAD06

Electricians (Except Industrial and Power System)

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
1	Integration	Partial	EV subsystems and integration	Mechatronics	Siemens Mechatronic Systems Certification Program Level1 (University of Windsor)	Siemens Mechatronics Certification Program Levels 2 and 3	Mechatronic Fundamentals (Conestoga College)
1	Installation	Partial	EV electrical system installation	Electronics	more information needed	Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	

Industrial and Manufacturing Engineers

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
1	Electrical engineering	Net-new	EV electrical engineering	EV electrical engineering	Engineering of Electrified Vehicular Systems (University of Michigan-Dearborn)		
2	Integration	Partial	EV subsystems and integration	Mechatronics	Siemens Mechatronic Systems Certification Program Level 1 (University of Windsor)	Siemens Mechatronics Certification Program Levels 2 and 3	
2	Powertrain	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electric Vehicle Engineering Academy ACAD06
2	Propulsion (powertrain)	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electric Vehicle Engineering Academy ACAD06

Machining Tool Operators

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
1	Electric motors	Net-new	Electric motors course	Electric motors	SAE Fundamentals and Applications of Electric Motors for Automotive Industries C1870		
2	Integration	Partial	EV subsystems and integration	Mechatronics	Siemens Mechatronic Systems Certification Program Level 1 (University of Windsor)	Siemens Mechatronics Certification Program Levels 2 and 3	Mechatronic Fundamentals (Conestoga College)
2	Subsystems	Partial	EV subsystems and integration	Mechatronics	Siemens Mechatronic Systems Certification Program Level 1 (University of Windsor)	Siemens Mechatronics Certification Program Levels 2 and 3	Mechatronic Fundamentals (Conestoga College)
2	Axles for EVs (powertrain)	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electronic Vehicle Engineering Academic ACAD06
2	Powertrain	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electronic Vehicle Engineering Academic ACAD06
2	Transmission systems	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electronic Vehicle Engineering Academic ACAD06

Machinists and Machining and Tooling Inspectors

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
1	Electric motors	Net-new	Electric motors course	Electric motors	SAE Fundamentals and Applications of Electric Motors for Automotive Industries C1870		
2	Integration	Partial	EV subsystems and integration	Mechatronics	Siemens Mechatronic Systems Certification Program Level 1 (University of Windsor)	Siemens Mechatronics Certification Program Levels 2 and 3	Mechatronic Fundamentals (Conestoga College)
2	Subsystems	Partial	EV subsystems and integration	Mechatronics	Siemens Mechatronic Systems Certification Program Level 1 (University of Windsor)	Siemens Mechatronics Certification Program Levels 2 and 3	Mechatronic Fundamentals (Conestoga College)
2	Axles	Partial	Axles for EVs (powertrain)	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electronic Vehicle Engineering Academic ACAD06
2	Powertrain	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electronic Vehicle Engineering Academic ACAD06
2	Transmission systems	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electronic Vehicle Engineering Academic ACAD06

Manufacturing Managers

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
1	Electric vehicles	Net-new	EV overview for engineers	EV overview	CADD Centre Electric Vehicle Technology Overview	CADD Centre Executive Diploma in Electric Vehicle System Design and Analysis	
2	Battery pack	Net-new	EV battery course	Batteries	SAE Introduction to Hybrid and Electric Vehicle Battery Systems C0626	SAE EV Batteries Course	
2	Electrical engineering	Net-new	EV electrical engineering	EV electrical engineering	Engineering of Electrified Vehicular Systems (University of Michigan-Dearborn)		
3	Electronics	Partial	Electronics for EVs overview	Electronics	more information needed		
3	Integration	Partial	EV subsystems and integration	Mechatronics	Siemens Mechatronic Systems Certification Program Level 1 (University of Windsor)	Siemens Mechatronics Certification Program Levels 2 and 3	Mechatronic Fundamentals (Conestoga College)
3	Powertrain	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electric Vehicle Engineering Academy ACAD06
3	Propulsion (powertrain)	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electronic Vehicle Engineering Academic ACAD06

Mechanical Engineering Technologists and Technicians

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
1	Electrical engineering	Net-new	EV electrical engineering	EV electrical engineering	Engineering of Electrified Vehicular Systems (University of Michigan-Dearborn)		
2	Chassis	Partial	EV chassis	EV assembly and chassis	more information needed		
2	Integration	Partial	EV subsystems and integration	Mechatronics	Siemens Mechatronic Systems Certification Program Level 1 (University of Windsor)	Siemens Mechatronics Certification Program Levels 2 and 3	Mechatronic Fundamentals (Conestoga College)

Mechanical Engineers

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
1	Electric vehicles	Net-new	EV overview for engineers	EV overview	CADD Centre Electric Vehicle Technology Overview	CADD Centre Executive Diploma in Electric Vehicle System Design and Analysis	
2	Electrical engineering	Net-new	EV electrical engineering	EV electrical engineering	Engineering of Electrified Vehicular Systems (University of Michigan-Dearborn)		
3	Battery pack	Net-new	EV battery course	Batteries	SAE Introduction to Hybrid and Electric Vehicle Battery Systems C0626	SAE EV Batteries Courses	

Mechanical Engineers (continued)

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
3	Electronics	Partial	Electronics for EVs for engineering	Electronics	more information needed		
3	Integration	Partial	EV subsystems and integration	Mechatronics	Siemens Mechatronic Systems Certification Program Level 1 (University of Windsor)	Siemens Mechatronics Certification Program Levels 2 and 3	
3	Powertrain	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electric Vehicle Engineering Academy ACAD06
3	Propulsion (powertrain)	Partial	EV powertrain course	Powertrain	Electric Vehicle Powertrain Systems (University of Windsor)	SAE Vehicle Architecture for Hybrid, Electric, Automated, and Shared Vehicle Design C2206	SAE Hybrid and Electric Vehicle Engineering Academy ACAD06

Motor Vehicle Assemblers, Inspectors and Testers

Sequence	Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
1	Electricity	Net-new	Electricity	Electricity fundamentals	Electrical Fundamentals ELEC1945 (Conestoga College)	Mechatronic Fundamentals (Conestoga College)	

5.2.3. Looking Forward

Amid transitions in the industry, we expect that new gaps will continue to emerge and/or become more pressing. Reskilling pathways and journeys will need to be refined on ongoing basis. As an example, while the data for this project did not explicitly identify automotive design as a gap, we anticipate it is a growing partial knowledge gap. The EV transition is transforming how cars are designed. Workers involved in the design of ICEVs will need to address this gap to transition to EV manufacturing.

Possible Future Gap: EV Automotive Design

Possible Future Gap	Type	Anticipated Need	Pathway	Short-Term Example	Additional Resources 1	Additional Resources 2
Automotive design	Partial	EV Automotive Design Course	EV Automotive Design	CADD Centre Executive Diploma in Electric Vehicle System Design and Analysis	Certificate in Electric Vehicle Design – AECEREVD (University of Toronto)	

6. Assessing Progress and Continuous Improvement

6.1. Overall Reskilling Capacity and Skill and Knowledge Mix

Progress toward the EV future will unfold along multiple dimensions. At the system level, demand for reskilling will to some extent be a function of how quickly society progresses in transitioning from ICEVs to EVs, both on the road and in manufacturing.

The reskilling pathways we define today will need to scale as demand increases, and also to adapt to reflect evolving needs for skills and knowledge in response to ongoing innovations in automotive manufacturing as EV technology continues to improve and the other transitions in progress play out.

Recent trends indicate that we may see a slowing in market adoption of EVs in the near term, providing a little more time for employers to plan for reskilling and support the development of learning opportunities that meet their needs, and for learning institutions to prepare to meet the anticipated demand.

6.2. Reskilling Ecosystem and Pathways

Progress must also be made in expanding and refining the reskilling pathways needed and ensuring the development of the courses and learning opportunities that will comprise them.

We anticipate that OEMs' needs will vary to some degree, and that each plant will have specific needs that cannot be anticipated by this report. The pathways presented here should form a foundation upon which employers and other interested parties can build. OEMs that are readying EV plants for launch will learn much in the process, and that knowledge may prove valuable in refining the learning available through the training and education providers in the ecosystem.

We should also facilitate and monitor progress in improving and enhancing the reskilling ecosystem and the learning opportunities it provides. Ontario has a wealth of excellent educational institutions, but more work is required to make the learning available in formats that meet the needs of reskilling workers. As the transition unfolds, we should measure how the offerings meet employers' current needs and how the ecosystem is improving with use.

6.2.1. Measuring Progress: Ecosystem and Pathways

As reskilling proceeds, automotive manufacturers will generate data. Information that would be valuable to ecosystem players, and the government of Ontario, which stewards the ecosystem, might include:

- Updated and refined lists of skills and knowledge gaps
- Availability of suitable training and education courses in Ontario, including assessments of capacity to meet anticipated demand
- Current and anticipated demand for training and education offerings (e.g. micro-credentials), organized by occupation, gap/pathway, and need
- Percent of ICEV workers finding roles in EV manufacturing; percent of ICEV workers leaving when their employer transitions to EV production

6.3. Workforce and Worker Progress

Managers should consider how to monitor and assess reskilling progress at the plant level, and also how to monitor the progress of individual workers. The journey described above lays out steps and includes prompts to create custom journeys for plants, occupations, roles, and individuals.

6.3.1. Human Factors: Caught Up in Transitions

For workers who have had a stable job for an extended period, the prospect of having to reskill or risk being displaced poses risks to mental health and wellness.

Experienced workers will have seen the industry and automobiles change considerably over the course of their careers, but the pace of change has been increasing in recent years, placing added pressure on workers. Moreover, in the automotive manufacturing context, the EV transition is an unprecedented shift from a mature technology (ICEV) to an emerging technology (EV). This will be new territory for many workers.

To complicate matters further, it is already clear that this transition will not be linear. Market forces and changing regulations will dictate how OEMs allocate their resources. Workers and plant-level management may not be able to accurately assess when their plant will make the shift to an EV platform. Lacking a reliable understanding of when their jobs will change, or what the plant will be producing once it does change, workers may find themselves living in a state of prolonged uncertainty.

Employers can address these risks in a variety of ways. Some of the change management measures suggested above can be rolled out in advance, to help make sure workers know that their employer wishes to retain them and plans to support them through the transition. It may also be advisable to put programs in place to collect and answer questions, and to make mental health and wellness supports available where appropriate.

6.3.2. Measuring Progress: Workforce and Workers

Employers will wish to be able to accurately assess the readiness of their workforce in advance of launching production[49], and also to measure how the workforce functions once in production. Measures might include:

- Qualitative metrics such as:
  - Self or peer assessment of comfort/readiness in new or modified roles
  - Self or peer assessments of confidence in ability to work independently
  - Worker assessments of readiness for the entire plant or segments thereof
  - Worker assessments of how easy it is for them to access knowledge and support
- Quantitative metrics such as:
  - Defects
  - Injuries and incidents
  - Measures of efficiency

6.4. Equity, Diversity, and Inclusion (EDI)

With many workers nearing retirement, Ontario's automotive manufacturing sector is expected to face a shortage of skilled workers as the transition to EV manufacturing proceeds[50]. Applying an EDI lens to all aspects of reskilling will be crucial in helping employers retain as many experienced employees as possible through the transition.

Efforts to support inclusive reskilling should consider diversity from a textured and intersectional perspective[51]. Some barriers to accessing learning may stem from differences that are not visible and may not be captured by employee surveys or labour force statistics. Factors such as cognitive or behavioural diversity and neuro-divergence may present barriers to accessing learning. Mid-career employees may have responsibilities outside of work, such as caring for children or elderly family members. Employees may have invisible disabilities that constrain the time and energy they have available to pursue learning in parallel with full-time work. Employees with the deepest experience may not have pursued formal learning in decades, and will need to adjust to a learning environment that has become far more technology-mediated in the interim. When barriers like these intersect with each other, or with factors such as gender, race, sexuality, and disability, reskilling workers may be in especially acute need of additional support.

Providing all employees with the support they need to pursue and complete their reskilling journeys will require nuance and care. Workers may be accustomed to concealing the ways in which they are different out of concern it might limit their career progression. Management must work to create and perpetuate a culture of inclusion and an environment where workers will feel safe asking for help. It may also be helpful to offer accommodations and additional support on a no-questions-asked basis. If the goal is to make reskilling easily accessible, management does not necessarily need to know why a given employee needs additional time or support to complete a given course of study.

For workers who require adaptation and accommodation (e.g. for disability), management should consider implementing a means for them to express their needs and concerns with the assurance that this information will remain confidential and will not be logged in records that are used to inform decisions around hiring for new roles or promotions.

Successful incorporation of EDI principles requires a journey of mutual learning. It is not enough to start a program—it must be actively supported and maintained over a period of years if employers wish to cultivate a culture of inclusion.

6.4.1. Measurement and EDI

As mentioned above, workers may fear that disclosing differences puts them at risk of discrimination. Employers working to create a safe environment and a culture of inclusion should be mindful of these considerations when formulating plans to measure progress.

Conclusion

The transition from ICEVs to EVs has just begun. As it progresses over the coming years, the need for reskilling will increase. We may also expect that the knowledge the workforce needs will continue to change to keep pace with ongoing innovation in advanced manufacturing and EV technology.

Ontario's EV training and education ecosystem must grow and mature if it is to support the needs of reskilling automotive workers. While Ontario boasts high-quality versions of all the components required to support employers and their workers along the reskilling journey, we have only just begun to put them together in ways that suit the needs of this segment of our workforce.

This study seeks to provide a framework that can serve as a scaffold. Over time, we will continue to learn more about how to best support workers in reskilling, and we will continue to refine our understanding of the knowledge workers require to produce EVs. Continuous improvement will be crucial to long-term success. All players in the transition have a role to play in helping ensure that Ontario's automotive manufacturing industry has access to the skilled, talented, and diverse workforce needed to cement the province's position in the automotive industry of tomorrow. If experienced automotive workers are adequately supported, they will be able to retain the quality jobs for which the automotive industry is known.

This is ultimately to the benefit of both individuals and Ontario's economy. In time, we anticipate more specialized EV pathways will emerge as industry works together with educational institutions and training providers. Anticipated change and growth in micro-credentials in Ontario will also contribute to the ongoing improvement and growth of the ecosystem, and long-term success for the industry.

Recommendations to Bolster Ontario's EV Reskilling Ecosystem
EMPLOYERS (OEMs)

1. More and better data describing the learning needs of reskilling workers will be of value. Employers will have the best information as to the knowledge reskilling workers need to acquire and the scale of demand for reskilling. To that effect:
    a. Employers should refine their understanding of the knowledge their workers need. Continuous refinement over time will be key, as the industry continues to undergo transitions.
    b. OEMs should consider the opportunity to collaborate with each other to encourage other ecosystem players such as learning institutions and governments to develop educational offerings for Ontario's EV industry (instead of an OEM by OEM approach).
2. Education and training providers have partnered with industry players (automotive and otherwise) to develop custom micro-credentials to meet specific needs. Employers should continue to explore these partnership opportunities, which offer potential to tap Ontario's wealth of excellent education providers.
3. Employers should engage with unions as important partners in reskilling initiatives and the broader EV transition.
4. Employers should monitor and track progress of reskilling initiatives in order to drive continuous improvement over the coming years.

EDUCATION AND TRAINING PROVIDERS

5. Ontario is positioned to be a leader in automotive reskilling education. Our educational institutions have begun to make EV-focused micro-credentials available, and should continue to pursue these efforts.
    a. Institutions with engineering and engineering technology programs should consider making EV-related courses available as micro-credentials. It may be especially fruitful to work with industry partners to identify existing courses that could be delivered to meet reskilling needs, providing Ontario-based workers opportunities to pursue reskilling from locally recognized institutions that confer credentials recognized in Ontario.
6. Increase efforts to leverage the stackability of micro-credentials to enable continuous learning that will significantly improve the job prospects available to manufacturing workers in Ontario.

GOVERNMENTS

7. Governments should encourage further collaboration between employers and education institutions, thus supporting Ontario becoming a leader in the automotive reskilling space. OVIN is strategically positioned to support and facilitate this collaboration.
8. Governments should continue the work already underway to emphasize micro-credentials as a new format for pursuing higher education and to support the development of industry-informed micro-credentials that help train the workforce needed to meet the needs of EV manufacturers.
9. Governments should build on existing initiatives (e.g., Canada-Ontario Job Grant) and explore additional avenues to stimulate private sector investment in workforce training.

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About the Ontario Vehicle Innovation Network (OVIN)

The Ontario Vehicle Innovation Network (OVIN) is the Government of Ontario's flagship initiative on the future of advanced automotive technology and smart mobility solutions – including connected vehicles, autonomous vehicles, and electric and low-carbon vehicle technologies. OVIN is led by the Ontario Centre of Innovation (OCI) and supported by the Ministry of Economic Development, Job Creation and Trade, the Ministry of Transportation, and the Ministry of Labour, Training and Skills Development. Through resources such as research and development support, talent and skills development, technology acceleration, business and technical supports, and demonstration grounds, OVIN reinforces Ontario's position as a global leader in the automotive and mobility sector.

OVIN has five main objectives:

1. Foster the commercialization of Ontario-made advanced automotive technologies and smart mobility solutions.
2. Showcase the Province of Ontario as the leader in the development, testing, piloting, and adoption of the latest transportation and infrastructure technologies.
3. Drive innovation and collaboration among stakeholders at the convergence of automotive and technology.
4. Leverage and retain Ontario's highly skilled talent, and prepare Ontario's workforce for jobs of the future in the automotive and mobility sectors.
5. Harness the Province of Ontario's regional strengths and capabilities, and bridge its automotive and technology clusters to promote the development of EV and power train technologies in Ontario.

For more information about OVIN, visit: www.ovinhub.ca.

Where Next Happens

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