DECEMBER 2023

Shifting gears

How Ontario's push to manufacturing zero-emissions vehicles will impact the workforce

PLACE Centre
Smart Prosperity Institute

Future Skills Centre
Centre des Compétences futures

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Abbreviations

AMTEC	Advanced Manufacturing Technical Education Collaborative
APRC	Automotive Policy Research Centre
ESP	Employment service provider
FOCAL	Future of Canada Automotive Labourforce
ICEV	Internal combustion engine vehicle
LDV	Light duty vehicle
MVBTP	Motor Vehicle, Body, Trailer and Parts
NAICS	North American Industry Classification System
NOC	National Occupational Classification
O*NET	Occupation Information Network
OEM	Original equipment manufacturer
PM	Primary metal
PSI	Post-secondary institution
RTRA	Real-Time Remote Access
STEM	Science, technology, engineering, and mathematics
ZEV	Zero-emissions vehicle

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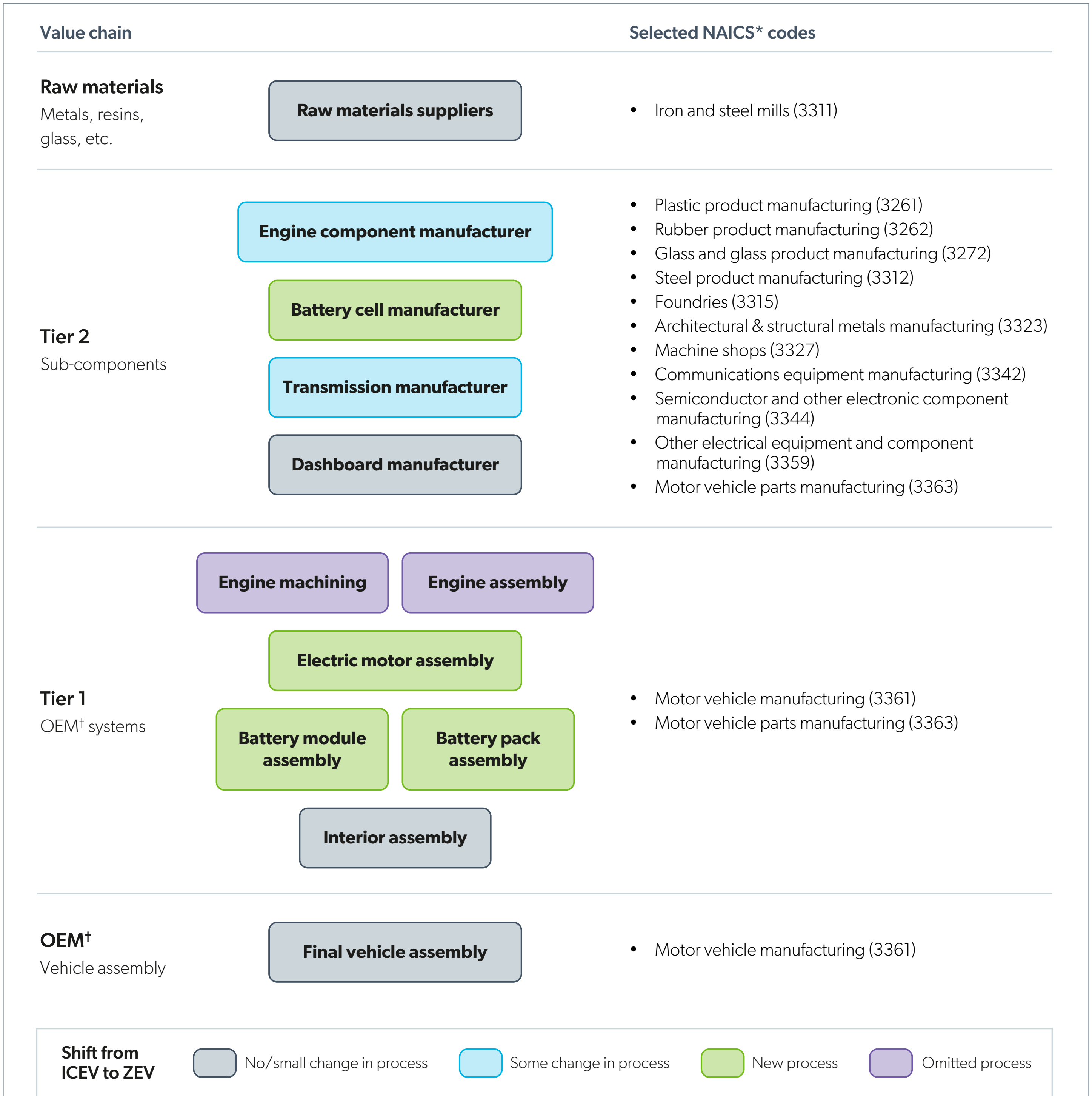
Executive summary

The automotive industry in Ontario is shifting gears, undergoing one of its biggest transformations so far. The transition to zero-emissions vehicles (ZEVs), as well as increasing digitization and automation, are revolutionizing the industry. Businesses, unions, educational institutions, and policymakers face a challenge in navigating an uncertain future about how this transition might play out in the coming years, and how the automotive manufacturing workforce will be affected. As the industry evolves, so will jobs and the skills and knowledge the workforce needs to fill emerging roles. Previous analysis has suggested that the shift towards ZEVs will create jobs and attract tens of billions of dollars of investment to the region, ultimately leading to the sustainability, rather than the growth, of Ontario's automotive sector.[1] By identifying what new skills requirements these jobs will bring, and by developing smart and collaborative approaches and policies to train, upskill, and reskill workers, Ontario and the communities in its automotive manufacturing hubs can begin to realize the benefits presented by the shift to ZEVs.

The differences in composition between ZEVs and internal combustion engine vehicles (ICEVs) will ultimately determine production requirements and thus, the skills and knowledge requirements of the workforce, as shown in Figure 1. A battery and electric motor in place of an engine, along with fewer overall components, will impact the number and type of jobs needed to manufacture a ZEV versus an ICEV. Additionally, the increased use of automation and digitization within the manufacturing process will alter the skills and knowledge requirements of existing workers.

Overall, the shift to ZEVs is not expected to dramatically change the size of the workforce in Canada's automotive and automotive parts sector. This means that the shift to ZEVs is about sustaining, rather than growing, Canada's automotive workforce. While there are questions about where production facilities and supply chain components will be built in the coming years, businesses, unions, educational institutions, and policymakers are looking to navigate these uncertainties to ensure the workforce is prepared. This report identifies anticipated skills changes and impacted occupations in the automotive sector out to 2030, shows where skills gaps are likely to emerge by comparing the current and expected skills needs, and offers recommendations to address these skills shortages and support the workforce.

Figure 1. Differences between the internal combustion engine vehicle (ICEV) and zero-emissions vehicle (ZEV) supply chain



*NAICS: North American Industry Classification System †OEM: Original equipment manufacturer

Key findings

Impacts on workers will centre around differences between ICEVs and ZEVS and changes in how vehicles are manufactured.

The differences in end-use technology revolve around changes to the powertrain. The main components of an ICEV powertrain—the engine and auxiliary systems—are unnecessary in a ZEV. Instead, these are replaced by a battery pack, consisting of modules with battery cells, and an electric motor. Additionally, changes in production processes will impact the needs of companies and the skills demanded of workers. These revolve around the increased adoption of automated solutions and changes in the manufacturing line between new battery facilities and other parts suppliers.

Greater automation and digital technologies in the automotive and battery manufacturing sector will not necessarily replace jobs, but will change the jobs required and the necessary skills to do these jobs.

Certain occupations and sectors will see increases in demand, especially those with electrical and chemical expertise. Skills in software design, coding, programming, and battery management will be in greater demand. Jobs like controls technicians, chemical engineers, electrical and electronics engineers, industrial engineers, materials engineers, manufacturing technologists, mechanical engineering technicians, and software developers have been identified as key occupations for the future of ZEV and battery manufacturing.

A lack of sufficient training or upskilling opportunities for new or transitioning workers working in the ZEV supply chain is a major issue affecting workforce planning.

Two-thirds (66.7%) of surveyed respondents identified a "lack of appropriate education/training options" for students/recent graduates as a main reason for various expected future skills shortages. Additionally, more than half (58.3%) of respondents identified "a lack of reskilling/retraining options for current workers" as another challenge.

There is a greater need for upskilling within the workforce than full retraining.

Stakeholders believe that existing workers in the auto sector will largely need to upskill (acquire new knowledge or skill sets on top of existing skills) rather than reskill or fully retrain (change existing skill sets). Many stakeholders believe that upskilling for many occupations could be completed in as little as one to four weeks.

A broad knowledge base, alongside technical and cognitive skills, are vital across the ZEV sub-sectors.

The top knowledge elements that currently rank as fundamental across the sub-sectors are the English language, production and processing, and mathematics. The top skills that currently rank as fundamental are critical thinking, monitoring, and operations monitoring. This shows that non-technical skills will be the most in demand across all industries, indicating a greater need for social/emotional skills training.

Automotive parts manufacturers and battery parts manufacturers are the sub-sectors that are most optimistic about the future transition.

In our survey of stakeholders, close to two-thirds (62.5%) of automotive parts manufacturers and 100% of battery parts manufacturers anticipate continued significant investment in the industry, government mandates to switch to ZEV manufacturing, and increases in demand out to 2030 and beyond. However, stakeholders from groups such as unions and training institutions were less optimistic, noting that they felt the scale of change required to capture this growth should not be underestimated.

Approximately half of survey respondents anticipate a high growth scenario for the future of the automotive sector.

Just over half of all the survey respondents (54%) thought a high growth scenario—with high levels of investment, clear policy pathways for critical minerals, and an abundance of skilled professionals and training opportunities—would most likely happen between now and 2030. The remaining perspectives were less optimistic, believing either a mid-growth or low-growth scenario was likely. This speaks to the uncertainty felt by automotive sector stakeholders.

Electronics and electrical product sub-sectors are expected to grow.

The computer and electronic product manufacturing sub-sector, as well as the electric equipment, appliance and component manufacturing sub-sector, are expected to grow because of their work on vehicle powertrains and semiconductors. In ZEVs, semiconductor content per car will double, and more battery factories will be required to keep pace with demand. To meet demand, the size and composition of these sub-sectors' workforces are expected to grow.

Key findings

The aging demographic of automotive manufacturing is viewed as a challenge for the sector.

Almost two-thirds of surveyed respondents (62.5%) thought the automotive manufacturing sub-sectors aging and retiring workforce would be a driver of future skills and labour shortages.

Employers are concerned about the opportunity costs of their employees undergoing training.

More than half of survey respondents (59%) identified financial cost as the biggest barrier to upskilling and reskilling workers, while half (50%) identified the time it takes to organise and deliver the training as another major barrier to upskilling and retraining.

The wages in the manufacturing sector serve as a barrier to the talent pipeline.

In 2022, Ontario's manufacturing sector had a lower average hourly wages ($30.83) than the overall hourly average wage ($32.94) across all industries for all workers (aged 15 and above).

Lack of transparency is one of the biggest current limitations holding back workforce planning.

There is a lack of information sharing between original equipment manufacturers (OEMs) and new plant facilities about the job descriptions, job requirements, and skills needs in ZEV and battery manufacturing, making workforce planning to meet future demand difficult.

Recommendations

1 Strengthen the mandates of the Canadian Automotive Partnership Council (CAPC) to address uncertainty about future skills training needs and tackle sectoral talent shortages.

This would allow for a more responsive and collaborative automotive workforce development system that goes beyond securing investments to sharing skills requirements, best practices, and resources, as well as informing education and training programs amongst automotive manufacturers/suppliers, workers, government, and educators.

2 Ensure new facilities that receive government support come with mandates for participation in CAPC.

This specifically targets automotive investments that receive government support and are above a certain threshold (i.e., expected to directly employ over 250 people).

3 Lower barriers to entering the workforce and upskilling for workers who have the necessary skills and interest in working in sectors throughout the ZEV supply chain

by making it easier to undertake a post-secondary degree or diploma after an apprenticeship and easier for newcomers to get their provincial certificates of qualification.

4 Create training programs that incorporate integration services for workers coming to Ontario from other parts of Canada and outside of Canada.

More courses should be provided by post-secondary institutions (PSIs) to help acculturate interprovincial and international newcomers to workplace norms, with workers awarded sectorally recognized micro credential upon course completion.

Table 1. Sub-sector summary of trends, occupations, and skills

Sub-sector (NAICS)	Trends impacting sub-sector	Future occupations in demand	Future skills in demand
Primary metal manufacturing (331)	• Increased use of advanced high-strength or ultra-high strength steel • Different processes and equipment required to manipulate high or ultra-high strength steel	• Engineers • Technologists • Technicians • Construction millwrights • Industrial mechanics • Plant supervisors	• Chemical • Mechanical • Equipment maintenance and selection • Operations monitoring • Computers and electronics • Communication • Production and processing • Critical thinking
Plastics and rubber production manufacturing (326)	• 30% reduction in quantity of plastics • New areas of growth in temperature resistant plastics • Absence of certain rubber components and alternative design of existing components	• Data analyst • Artificial intelligence and machine learning specialists • Software and application developers • Plant supervisors	• Chemical • Mechanical • Material handling • Engineering and technology • Programming • Automation • Problem solving • Mathematics • Computer and electronics • Critical thinking
Non-metallic mineral product manufacturing (327)	• Increased automation in the long term	• Engineers • Technologists • Technicians • Construction millwrights • Industrial mechanics	• Computer and electronics • Communication skills • Production and processing • Critical thinking • Operations monitoring
Fabricated metal product manufacturing (332)	• Lightweighting of products • Requirement for certain products to be conductive • Adapted products to accommodate increased working with high-strength steel, aluminium and plastics	• Mechanical engineers • Industrial engineers • Manufacturing engineers • Computer programrs • Maintenance and plant supervisors	• Engineering and technology • Design • Production and processing • Electrical and fire safety • Programming • Problem solving • Decision making • Critical thinking • Computers and electronics • Mathematical
Computer and electronic product manufacturing (334)	• Semiconductor content per car doubles • Faster innovation cycle	• Materials (including electronics) assemblers • Maintenance and plant supervisors	• Complex problem solving and troubleshooting • Systems knowledge • Design • Programming • Critical thinking • Production and processing • Computer and electronics • Mathematical • Operations monitoring • Communication skills

Sub-sector (NAICS)	Trends impacting sub-sector	Future occupations in demand	Future skills in demand
Electrical equipment, appliance and component manufacturing (335)	• Increased battery manufacturing • Increased research and development	• Chemical engineers • Chemists • Material scientists • Electrical engineers • Mechanical engineers • Maintenance and plant supervisors	• Electrical • Mechanical • Equipment maintenance • Systems analysis and evaluation • Critical thinking • Production and processing • Computer and electronics • Mathematical • Operations monitoring • Communications skills • Battery knowledge
Transportation equipment manufacturing (336)	• Absence of internal combustion engine • Power electronic components result in different assembly processes and machinery, automation and controls • Fewer components	• Software developers and engineers • Battery management system engineers • Plant supervisors • New hybrid roles between millwright and general operator	• Production and processing • Critical thinking • Communication skills • Mechanical • Computer and electronics • Systems knowledge • Battery knowledge

Introduction

Ontario's automotive manufacturing sector is establishing what a shift towards ZEVs means for the province. According to the Government of Ontario, over the past two years, the province has attracted $16.5 billion in investments from global automakers, the Canadian federal government, and ZEV batteries and battery materials[2] suppliers to grow its emerging ZEV and battery manufacturing supply chain. Specifically, investments from original equipment manufacturers (OEMs), automotive parts manufacturers, and others have been directed towards Ontario's Windsor–Ottawa automotive corridor. These investments include:

- Stellantis and LG Energy Solutions' $5 billion battery cell factory in Windsor, ON;
- General Motors' $2.3 billion investment in upgrading its Brampton and Ingersoll, ON facilities;
- Ford's $1.8 billion retooling of its Oakville, ON plant; and,
- Volkswagen's battery manufacturing plant in St. Thomas, ON.

These current and future investments will create thousands of new jobs in Ontario, both within these production facilities and throughout the automotive parts supply chain. While the benefits are clear, this industry-wide shift is also bringing uncertainty to manufacturers. While ZEVs will help Ontario sustain its vehicle assembly industry, these shifts will impact workers. Technological differences between internal combustion engine vehicles (ICEVs) and ZEVs mean that some automotive components currently manufactured in Ontario might become obsolete. Some workers may need to consider transitioning to growing parts of the automotive supply chain if the outlook for their current role is not favourable. Additionally, individuals will need to ensure they have the necessary skills to fill new and emerging roles as certain sectors or sub-sectors grow. If workers are not supported through this shift, or the shift is poorly managed by governments and industry, the impacts could prove disruptive for workers and their communities.

To ensure workers are equipped with the necessary skills to fill emerging roles in the growing ZEV and battery manufacturing industry, support will need to be provided through public policy, industry leadership, and changes in training and education. Companies will need to step in and offer battery-specific training and education for the local workforce. Sourcing new entrants into the workforce, as well as upskilling and retraining existing workers, will allow for a more diverse workforce and provide higher-quality jobs. Colleges and universities will need to design new training programs and update current curricula. Unions will need to ensure workers have the necessary support to succeed in an evolving industry. And governments will need to offer funding, leadership, and coherence to ensure all other groups have the clarity and supports needed to succeed in their roles.

This report supports these stakeholders in their efforts by lending insight into the scale of this change, the skills needs of workers in an evolving sector, and which challenges will need to be overcome. This report begins by identifying the changes in production patterns between ICEVs and ZEVs, thereby identifying which segments of the supply chain will be most impacted by this shift. After examining the growing ZEV supply chain, this report details the impacts this shift will have on workers and skills, examining each sector involved. This report focuses on ZEV production in Ontario, meaning the sectors selected are those with production in the province. Finally, this report details several trends impacting workers across the supply chain and inhibiting the training and upskilling of workers needed to fill emerging roles. The analysis in this report can help ensure this shift leaves workers, employers, and communities well-positioned to reap the benefits of this shift towards ZEVs.

What is changing in the shift from ICEVs to ZEVs?

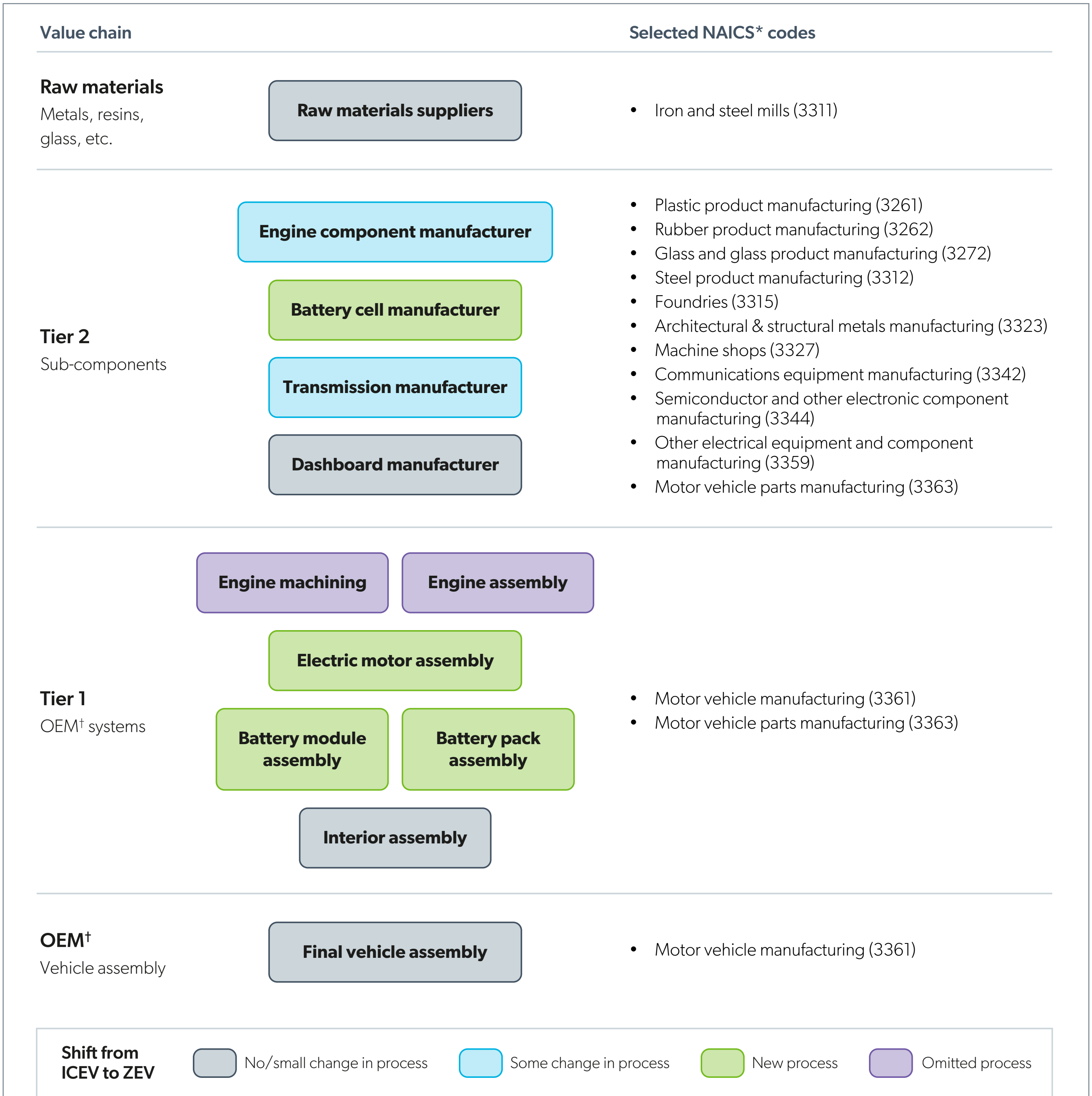
Changes in production requirements—and therefore skills and labour demand—are driven by differences in the composition of ICEVs and ZEVs. The key difference between the two technologies lies in changes to the powertrain.[3] The main components of an ICEV powertrain—the engine and auxiliary systems—are replaced by a battery pack, consisting of modules with battery cells, and an electric motor. From a manufacturing perspective, the shift from ICEVS to ZEVs will require some specific changes. First is the replacement of the traditional engine with an electric motor, freeing automakers from the complex and labour-intensive assembly of ICEV engines and allowing them to focus instead on relatively simple electric motors. Because electric motors have fewer parts with difficult-to-handle flexible materials, automakers can generally deploy more automated equipment to build them.[4] Second, there are significant differences in the manufacturing of ZEV motor components. Instead of the intricate casting and machining processes necessary to make ICEV components, less complex machining methods can be used to manufacture and install components for electric motors.[5] In this sense, the switch to ZEV production affects not only OEMs, but also their suppliers who will have to master new manufacturing processes and greater quality control for more complex electrical systems. The final distinct difference in powertrain production is the integration of battery packs which are often assembled by automakers in-house by piecing together battery modules. Entirely absent in ICEVs, this process will mean that automakers will require new battery expertise and processes for battery pack assembly and connection to the broader ZEV systems.

In automotive industrial hubs, such as Ontario, the shift to ZEVs will inevitably impact the province's manufacturing sector and its workers. Manufacturing sub-sectors within component manufacturing—such as plastics and rubber products, primary metal, and fabricated metal products—along with electrical component and motor vehicle manufacturing are likely to be impacted by new processes, materials, and digitization. While there is valid concern over reduced labour requirements in producing ZEVs due to the availability of automation when handling the less numerous and less complex ZEV components, the use of battery technology presents opportunities for the creation of a lot of high-value, good-paying jobs in mechanical engineering, electrical engineering, and even chemical engineering.[6] Analysis in this report identifies that the transition to ZEVs is not anticipated to lead to net increases in employment, but will most likely replace existing jobs in Ontario's auto assembly plants. In other words, ZEVs will help Ontario to sustain, rather than grow, its vehicle assembly industry.[7]

Mapping the supply chain

This section details how the shift from ICEVs to ZEVs will impact every stage of the supply chain, as represented in Figure 2. Industry groups and their North American Industry Classification System (NAICS) codes that sell more than 1% of their output to the two traditional automotive sub-sectors—motor vehicle manufacturing and motor vehicle parts manufacturing—were included in this analysis and positioned in the process based on their role and output within the identified supply chain (for a more detailed methodology see Appendix 1). This analysis provides a foundation for discussing the impacts this industry-wide shift will have on workers since it informs how sub-sectors and industry groups will be affected.

Figure 2. How the shift to zero-emissions vehicles (ZEVs) will affect the supply chain



*NAICS: North American Industry Classification System †OEM: Original equipment manufacturer

Raw materials

The first stage of the ZEV and battery production supply chain is raw materials. This part of the supply chain is currently a highly concentrated global market with several major mining and processing companies. Primary materials for the existing ICEV supply chain are carbon steel, aluminum, resins, glass, and composites, to name a few.[8] Meanwhile, the strong market growth of ZEVs has significantly increased raw material demand for battery materials such as lithium, nickel, cobalt, and graphite, with the World Bank estimating that the global demand for such ZEV battery minerals will increase four to five times by 2050.[9]

Mines and mineral deposits used for automotive manufacturing are distributed across Canada. Quebec, Ontario, and Newfoundland and Labrador are the provinces with the largest deposits of raw materials necessary for ZEV batteries.[10] While metals like nickel are more readily mined, other battery metals, such as cobalt and lithium, are hardly produced, and production is often not at "battery grade" quality.[11] Quebec is by far the Canadian province with the most developed battery metals industry, while Ontario is further behind, especially regarding lithium mines. Although several prospective projects within Ontario could change this—such as the lithium refinery announcement by lithium development company Avalon Advanced Materials Inc. in Toronto—new mines or refineries are not expected to become operational until 2030 or later.[12]

When considering the raw materials components of the supply chain most relevant for Ontario, only Iron and steel mills (NAICS 3311) merit inclusion. Hamilton has one of Canada's highest concentrations of steel manufacturing activity, with large steelmakers and steel product manufacturers such as Stelco Inc. and ArcelorMittal Dofasco Inc.[13] The iron and steel mills sub-sector could be impacted as ZEVs require lighter body materials to counteract the extra weight of the battery.[14] As a result, there could be a shift from iron and steel to aluminum, which is lighter and stronger. The industry however, expects ZEV manufacturing to produce stimulus for iron and steel through advanced high-strength steel.[15] No mining or refining sectors were relevant for inclusion in Ontario. This is primarily due to the province's lack of existing mining or refinery capacity and the reality that operations are not expected to commence until 2030 or later.

Tier 2

Tier 2 is the part of the supply chain that includes the manufacturing of sub-components and systems such as electronic, mechanical, composite components, wiring, aluminum and rubber components, and software. Tier 2 suppliers are often experts in their specific domain. This means that while many Tier 2 firms supply parts that end up in cars, they also support many non-automotive customers and often do not sell directly to OEMs (instead, they sell to Tier 1 suppliers). These firms make up a highly fragmented market with many segments and small players, such as family-owned businesses. With the shift to ZEVs, there will be an expanding need for electronic components and lightweight fabrication within each vehicle, bolstering demand from manufacturers.[16]

For Tier 2 suppliers, there are major changes in engine component manufacturing in order to include an electric motor, and with that change comes a high share of new, adjusted, or omitted components.[17] Components and transmissions for ICEVs are expected to be most impacted.[18] According to EY research, 33% of all components in the traditional car architecture will become obsolete.[19] For example, the UBS Group compared the Chevrolet Bolt's electric motor to a four-cylinder internal-combustion engine and found that the e-motor had three moving parts compared to the ICEV's 113.[20] Of the engine and transmission components that remain in ZEVs, some might need to be manufactured differently with different materials or processes. For existing workers, the result might not be a change in skill set (reskilling) but a requirement for existing skills to be adapted (upskilling) and for new process knowledge to be acquired. The Motor vehicle parts manufacturing sub-sector (NAICS 3363)—which comprises motor vehicle transmissions parts and powertrain parts manufacturing, other engine equipment manufacturing, and mechanical power transmissions equipment manufacturing—is likely to be negatively impacted as there are fewer motor vehicle parts in ZEVs. Similarly, Rubber product manufacturing (NAICS 3262) could be adversely affected due to the absence of timing belts and rubber engine parts in ZEVs.

Some of these adverse impacts could be offset through the growth of the battery sector in Canada. The most valuable component of the ZEV is its battery, particularly the battery cells, which can account for up to 50% of the value of today's ZEVs.[21] A recent analysis identified the potential for a domestic ZEV battery supply chain to create up to 250,000 jobs by 2030 and add $48 billion to the Canadian economy annually.[22] Cell production is the first stage in the three-stage process of ZEV battery manufacturing. Currently, battery cells are typically produced by specialized Tier 2 suppliers, often from the consumer electronics industry and headquartered in Asia.[23] However, recent investments in battery and battery component manufacturing will mean more production taking place in Ontario. Tier 2 suppliers manufacture vehicle components across Ontario, primarily in the south-east in Toronto, Hamilton, Kitchener-Waterloo, and Windsor-Essex. Electrical components are also manufactured widely across the province. More localized sub-sectors include steel product manufacturing, predominantly in Barrie and Toronto, and machine shops around Mississauga and Ottawa.[24] Specifically regarding batteries, the recently announced Stellantis and LG Energy Solutions investment in Windsor, ON is Canada's first large-scale battery cell manufacturing facility,[25] while a second battery plant from Volkswagen is planned in St. Thomas, ON.

Tier 1

The next stage in the supply chain is Tier 1, which is the supply chain segment responsible for manufacturing systems for original equipment manufacturers (OEMs). This market contains several major segments—exterior, chassis, powertrain, interior, and electronics. OEMs are supplied by homegrown Tier 1 companies like Magna, Linamar, and Martinrea[26] and are subject to a specific geographic logic. Tier 1 suppliers are often near vehicle assembly plants. This is due to Tier 1 suppliers supplying products directly to an OEM, automakers' preference for just-in-time (and just-in-sequence) production systems, and the high cost of shipping built products. The province's largest Tier 1 companies are in southern Ontario, particularly in Woodstock, Brampton, Chatham, and Guelph. For battery manufacturing, Stellantis and LG will manufacture and assemble battery modules at their battery cell production facility in Windsor, ON. Battery pack assembly in Canada is currently limited — in Ontario, only Ford in Oakville assembles battery packs for Light duty vehicles (LDVs). It is likely that Stellantis and General Motors also will assemble battery packs as their Canadian ZEV footprint grows.[27]

The rise of ZEVs poses risks for Tier 1 suppliers, who make systems directly for the industry and have historically focused on ICEVs. Of the selected sub-sectors, both Motor vehicle manufacturing (NAICS 3361) and Motor vehicle parts manufacturing (NAICS 3363) will be impacted as major systems essential to ICEV engines are absent from ZEVs.[28] One key absence is the fuel tank found in the chassis system, which is removed in favour of a battery power system.[29] Similarly, powertrain systems will also be greatly impacted. The powertrain contains the drive controls, engine, transmission, and cooling system. Using a battery pack and removing an internal combustion engine will simplify powertrain design by eliminating multi-speed transmission, radiators, fuel injectors, valvetrains, and exhaust systems.[30] This substitution will be paired with an expanding need to invest in electrical and battery systems to integrate the chassis and powertrain.[31] Instead of the engine, ZEVs have an electric motor assembled in this section of the supply chain as part of the electrical and electronics system. Within the battery space, module assembly and battery pack assembly are the second and third stages of battery manufacturing respectively, and are the two battery-specific activities included in Tier 1. While both aspects are heavily automated, a significant amount of indirect labour is involved in operating machinery and equipment, controlling the production process, and quality inspection.[32]

OEM

The final stage included is vehicle assembly at the OEMs. The Motor vehicle manufacturing sub-sector (NAICS 3361) is involved in this part of the supply chain. This sub-sector is a highly concentrated market, with recent entrants focused on ZEV production. Vehicle assembly has long been critical to Canada's economy, and particularly that of Ontario. Ontario is a part of the largest automotive production network in the world.[33] Ontario is currently home to ten LDV plants operated by five automakers: Stellantis in Brampton and Windsor, Ford in Oakville, General Motors in Oshawa and Ingersoll, Honda in Alliston, and Toyota in Cambridge and Woodstock.[34] However, Canada's annual vehicle production has decreased consistently over the past two decades. During this time, five LDV plants closed while only one opened.[35] Developing a ZEV battery supply chain represents an opportunity to retain much of Ontario's existing vehicle assembly footprint, retain many jobs that have come under threat recently, and even regain some of the production capacity that has been lost. Initial investments to refurbish Ford, General Motors, and Stellantis assembly plants so that they can produce ZEVs represent an important first step in rebuilding and modernizing Ontario and Canada's vehicle assembly industry.

Box 1

Where do stakeholders feel the industry is going?

While there is a shared desire amongst governments, industry stakeholders, civil society groups, and communities to manufacture ZEVs and batteries in Ontario, stakeholder perspectives differ on the sector's trajectory. As part of the analysis conducted for this report, ZEV and battery manufacturing stakeholders in Ontario were asked in a survey where they felt the industry was going in the coming decade. Respondents were asked to select one of three scenarios they thought would most likely occur in the ZEV and battery manufacturing sector between now and 2030. These scenarios were:

Scenario 1: High growth

There are very high levels of investment in OEMs and battery manufacturing plants. Clear policy pathways for development of critical minerals and mining capacity are developed and pursued. The sector creates an abundance of skilled professionals and training opportunities.

Scenario 2: Medium growth

There are relatively lower levels of investment in OEMs and battery manufacturing. A lack of clear critical mineral policies muddies pathways for establishing domestic battery hub. Some retraining and reskilling opportunities are developed to help meet increased demand, but labour shortages remain.

Scenario 3: Low growth

There are very low levels of additional investment in the OEM and battery sectors. A lack of clear critical mineral policies muddies pathway for establishing domestic battery hub. Labour shortages and limited retraining and reskilling opportunities inhibit the growth of industry and deter future investments.

Survey respondents (n=48) comprised auto assembly/OEMs (12.8%); auto parts manufacturers (20%); academia/think tanks/training institutions (20.5%); battery cell, pack, and module manufacturers (7.7%); labour union representatives and chiefs (7.7%); and sectoral/umbrella body representatives (30.8%).[36] A little more than half of respondents (54%) thought the high growth scenario (Scenario 1) would be most likely to happen between now and 2030, while another 41.5% thought the medium growth scenario (Scenario 2) was likeliest. From a stakeholder or industry group standpoint, the auto and auto parts manufacturers were the most optimistic. Close to two-thirds (62.5%) answered that the high growth scenario (Scenario 1) was most likely to happen between now and 2030. In contrast, a little more than a third (37.5%) thought the medium growth scenario (Scenario 2) was most likely to happen. Most of the reasoning provided by respondents for choosing Scenario 1 was based on the significant investment in the industry, government mandates to switch to ZEV manufacturing, and expected increases in ZEV demand at the time of survey response. Additionally, all battery parts manufacturers surveyed thought the high growth scenario (Scenario 1) was the most likely. For auto and auto parts manufacturers selecting the medium growth scenario, the hesitance was due to a fear that the growth would be short-lived and the difficulty of competing with incentives from other countries.

The combination of labour unions, sectoral representatives, and training institutions was less optimistic than the rest of the respondents. Half (50%) thought the medium growth scenario (Scenario 2) would be most likely, while a little less than half (43%) thought the high growth scenario (Scenario 1) would be most likely. Only 7% of these respondents thought the low growth scenario (Scenario 3) would be the most likely. The reasoning for the medium growth selection across responses was the length of approval time for critical minerals extraction and disjointed government policies and coordination. This subset of respondents also thought that rather than taking the lead, the federal government is trying to—and may be unable to—catch up with investments and incentives from the United States. These responses reflected a perspective that there is a lack of coordination at different government levels, particularly regarding critical minerals, with provinces taking their own separate steps and the federal government struggling to coordinate everyone's distinct approaches. For the minority that selected the low growth scenario, the reasoning was that there was no historical precedent for thinking that the combination of factors needed to avoid the low growth scenario (such as better information sharing between and across stakeholders, improved journeyperson-to-apprentice ratios, timely qualification for skilled tradespeople, etc.) would happen in Ontario within ten years. Although our analysis excludes critical mineral extraction, refining, and battery recycling, these views are still worth reporting as they come from those most interested in, and affected by, changes throughout the ZEV and battery manufacturing supply chain.

How will this shift impact workers?

Throughout this report's analysis of the ZEV and battery value chain, which is done on a sector-by-sector basis, it should be acknowledged that certain trends exist that impact all sectors throughout the supply chain. The accelerated rise of new technologies, digitization, and new production processes are revolutionizing the automotive sector. Manufacturers are increasingly installing smart robotic machinery, implementing advanced manufacturing, and using analytics to perform more complex tasks and increase efficiency. Although the greater use of robotics and computerization will reduce the number of jobs in assembly and production, the number of manufacturing jobs requiring information technology and data science skills will increase.[37] As the increased adoption of automation solutions alters production processes, there will also be increased demand across the supply chain for workers with competencies in maintenance and quality control, production and planning, and logistics.[38] These trends and their impacts on workers are expected to impact the entire supply chain (such as labour shortages), are explored in more detail in this report's Outlook for workers manufacturing ZEVs section.

Methodology used in skills analysis

To capture the extent of the ZEV and battery manufacturing supply chain, this report adapted a methodology previously used by the Future of Canada Automotive Labourforce (FOCAL) Initiative for categorising the automotive manufacturing supply chain.[39] This methodology stems from an Automotive Policy Research Centre (APRC) report which identified as many as 200 automotive parts manufacturers and suppliers classified by Statistics Canada in addition to the core automotive manufacturing NAICS of Motor vehicle manufacturing (NAICS 3361) and Motor vehicle parts manufacturing (NAICS 3363).[40] For greater precision, this report also used 2020 inter-industry trade data (symmetric input-output tables) from Statistics Canada to work out the trade volumes between the aforementioned core automotive manufacturing NAICS sub-sectors and several associated sub-sectors based on the FOCAL sub-sector listings.

NAICS codes were used at the 4-digit level to maintain a standard level of detail. The 4-digit NAICS industry groups were included in this analysis if they made up 1% or more of the total volume of trade conducted by any of the two core sub-sectors.[41] In cases where the available data was only at the 3-digit NAICS level, researchers made the same calculations at the 3-digit NAICS level and then selected the most relevant 4-digit NAICS for auto manufacturing that also were shown in listings developed by FOCAL. In cases where there were both 4-digit and 3-digit sub-sector groupings, the 4-digit industry group with the largest percentage was selected. The 4-digit NAICS industry groups used in the rest of this report are shown in Table 2 below.

Table 2. North American Industry Classification System (NAICS) codes and industry groups used for analysis

Industry group	NAICS 2022 code
Plastic product manufacturing	3261
Rubber product manufacturing	3262
Glass and glass product manufacturing	3272
Iron and steel mills and ferro-alloy manufacturing	3311
Steel product manufacturing from purchased steel	3312
Foundries	3315
Architectural and structural metals manufacturing	3323
Machine shops, turned product and screw, nut and bolt manufacturing	3327
Communications equipment manufacturing	3342
Semiconductor and other electronic component manufacturing	3344
Other electrical equipment and component manufacturing	3359
Motor vehicle manufacturing	3361
Motor vehicle parts manufacturing	3363

To understand the importance of skills and knowledge across the ZEV and battery supply chain, this analysis compiled a comprehensive dataset linking Canadian industry and occupational codes with their associated skills and knowledge profiles.[42] This dataset links labour market information related to skills and knowledge, National Occupational Classification (NOC) codes, and inter-sectoral industry and trade data (for a complete list of NAICS and NOC codes included in the analysis, please refer to Appendix 2). The Occupation Information Network (O*NET) database was used as a foundation for the skills and knowledge component. Developed by the U.S. Bureau of Labor Statistics, the O*NET database is one of the most widely used and comprehensive databases for occupational information, including information related to skills, knowledge, abilities, and tasks.[43] This analysis focused on the 35 skills identified within the database as classified broadly within basic and cross-functional skills as well as the 33 knowledge pieces identified within the database. Basic skills, including content and process skills, enable workers to develop capacities that further allow for learning and acquiring knowledge. These include active listening, reading, critical thinking, and monitoring.[44] Cross-functional skills allow workers to undertake activities across tasks, including coordination, problem solving, operations monitoring, decision making, and management.[45] For a detailed overview of the classification of 35 skills and 33 knowledge, please see Appendix 3. Due to their fundamental nature, basic content skills[46] have the highest importance scores across jobs and sectors. They have been excluded from the analysis because they offer little insight into skills demand beyond identifying that reading and writing will be in demand for all positions. However, basic process skills, such as critical thinking and monitoring, are included in this analysis. The O*NET assigns "importance" scores to skills and knowledge attributes, which quantify how proficient an individual must be at a particular skill to perform in a given occupation. This analysis emphasizes the importance of skills and knowledge profiles within occupations to illustrate the most needed skills.

As part of the foresight analysis to understand where the automotive industry might be going in the coming decade, ZEV and battery manufacturing stakeholders in Ontario were interviewed or asked to complete a survey. Respondents answered questions specific to their professional expertise, focusing on recruitment of workers, current context, and beliefs about the future of the sector out to 2030. This foresight exercise provides an indication as to how the transition to ZEVs will impact the skills and knowledge requirements of the automotive workforce.

Overview of skills analysis across all sectors

Table 3 shows the highest-ranked weighted average importance scores for skills and knowledge across the entire ZEV supply chain using 2021 labour market data. The reported skills and knowledge scores are weighted by the number of people employed in a NOC code across sub-sectors. Basic process skills, like those mentioned above, and cross-functional skills, like operations monitoring, time management, and judgment and decision making, score the highest across all selected sub-sectors. Even though this report looks at the manufacturing sector where technical skills are pertinent, the importance of scores like critical thinking and monitoring are higher than those of technical skills. This finding does not render technical skills inconsequential, but highlights the importance of the broad-based skills profiles needed for most jobs in the auto and ZEV manufacturing sector. Meanwhile, knowledge in the English language, production and processing, and mathematics score the highest across all selected sub-sectors.

When discussing future skills needs of sub-sectors, this report will use the terms used in the survey. Some of these terms differ from what the NOC categorizes them as. For example, "maintenance and plant supervisors" was used in the survey to cover NOC 9201 (Supervisors, processing and manufacturing occupations) and NOC 9202 (Supervisors, assembly and fabrication). Similarly, "assemblers" was used in our survey to cover NOC 9420 (Mechanical, electrical and electronics assemblers and inspectors). This decision was made to simplify choices for respondents and reflect the everyday terms used at work or when hiring. It also reflects the reality on the shop or plant floor as communicated by stakeholders, whereby responsibilities overlap across NOC titles and the main difference in occupation titles can be experience or seniority. This gap between titles and responsibilities is in contrast with occupations like Machinists (NOC 7210 minor group) and Machine (tool) operators (NOC 9410 minor group), whereby the difference is mainly in the trade certification and apprenticeship, regardless of their common work experience.[47]

Many of the occupations identified in this report can be found not only in sectors within the ZEV supply chain, but also in other NAICS sectors across the economy. This context, along with our inclusion of atypical NAICS, makes it difficult to pinpoint precisely how many individuals are employed in specific occupations, such as millwrights, technicians, or mechanical engineers, within the automotive supply chain. Table 4 details the occupations found in multiple sub-sectors throughout the ZEV supply chain with the highest overall employment, offering a sense of scale for these changes in labour and skills needs.

Table 3. Summary of weighted-average skills and knowledge importance scores

Top skills	Weighted average
Critical thinking	115.0
Monitoring	110.1
Operations monitoring	104.9
Time management	103.7
Judgment and decision making	103.0
Coordination	101.9
Complex problem solving	100.9
Social perceptiveness	96.9
Quality control analysis	93.7
Operation and control	91.4

Top knowledge	Weighted average
English language	116.2
Production and processing	110.9
Mathematics	109.2
Customer and personal service	102.2
Mechanical	101.7
Administration and management	94.8
Computers and electronics	87.0
Education and training	83.5
Public safety and security	83.3
Administrative	78.0

Table 4. National Occupational Classification (NOC) title and total number of Ontario workers employed in the occupation.[48]

Occupation	Total employment, Ontario
Material handlers (manual)	85,630
Motor vehicle assemblers	49,345
Software engineers and designers	47,365
Shippers and receivers	40,550
Manufacturing managers	30,740
Welders	26,090
Sales and account representatives, wholesale trade (non-technical)	25,930
Mechanical engineers	23,075
Construction millwrights and industrial mechanics	22,400
Machinists	13,560
Supervisors, supply chain, tracking and scheduling co-ordination occupations	11,955
Industrial engineering and manufacturing technologists	8,040
Industrial electricians	7,635
Tool and die makers	7,260

Occupation	Total employment, Ontario
Industrial and manufacturing engineers	7,060
Supervisors, motor vehicle assembling	6,890
Mixing machine operators, plastics processing	6,350
Electronics assemblers	5,450
Metalworking machine operators	5,095
Labourers in metal fabrication	4,475
Mechanical assemblers	3,875
Labourers in rubber and plastic products manufacturing	3,145
Plastic products assemblers and finishers	2,210
Machine operators, mineral and metal processing	2,120
Supervisors, plastic and rubber products manufacturing	1,635
Other metal products machine operators	1,220
Supervisors, other mechanical and metal products manufacturing	1,015

Sub-sector analysis

Primary metal manufacturing

In this report, industries represented in primary metal (PM) manufacturing are Iron and steel mills and ferro-alloy manufacturing (NAICS 3311), Steel product manufacturing from purchased steel (NAICS 3312), and Foundries (NAICS 3315). This sub-sector comprises establishments primarily engaged in smelting and refining ferrous and non-ferrous metals in furnaces. The output of smelting and refining is used in rolling and drawing operations to produce sheet, strip, bars, rods, and wire, and in molten form to produce castings and other basic metal products. Ontario is the second-largest manufacturer of PM in Canada, behind Quebec, employing 29,231 workers in 2021.[49] The PM manufacturing industry is male-dominated, with men representing 83% of the provincial employment in 2021.[50] Almost one in three workers (31.1%) in the industry were aged 55 years and over.[51] Key occupations in PM manufacturing for ZEV manufacturing are machine operators of mineral and metal processing, supervisors of mineral and metal processing, labourers in mineral and metal processing, crane operators, and construction millwrights and industrial mechanics.

Current workforce profile

As the occupations within the sub-sector vary in terms of tasks performed and required education and work experience, skills profiles also vary by occupation. Individuals involved in PM manufacturing have strong critical thinking, monitoring, and operations monitoring skills, while quality control analysis remains less important. Workers in PM manufacturing also have strong expertise in the English language, knowledge and application of mathematics, and knowledge of machines and tools (including their designs, uses, repair, and maintenance). Knowledge in engineering and technology is of lesser importance for workers in this sub-sector.

Table 5. Summary of top weighted-average skills and knowledge importance scores in primary metal manufacturing

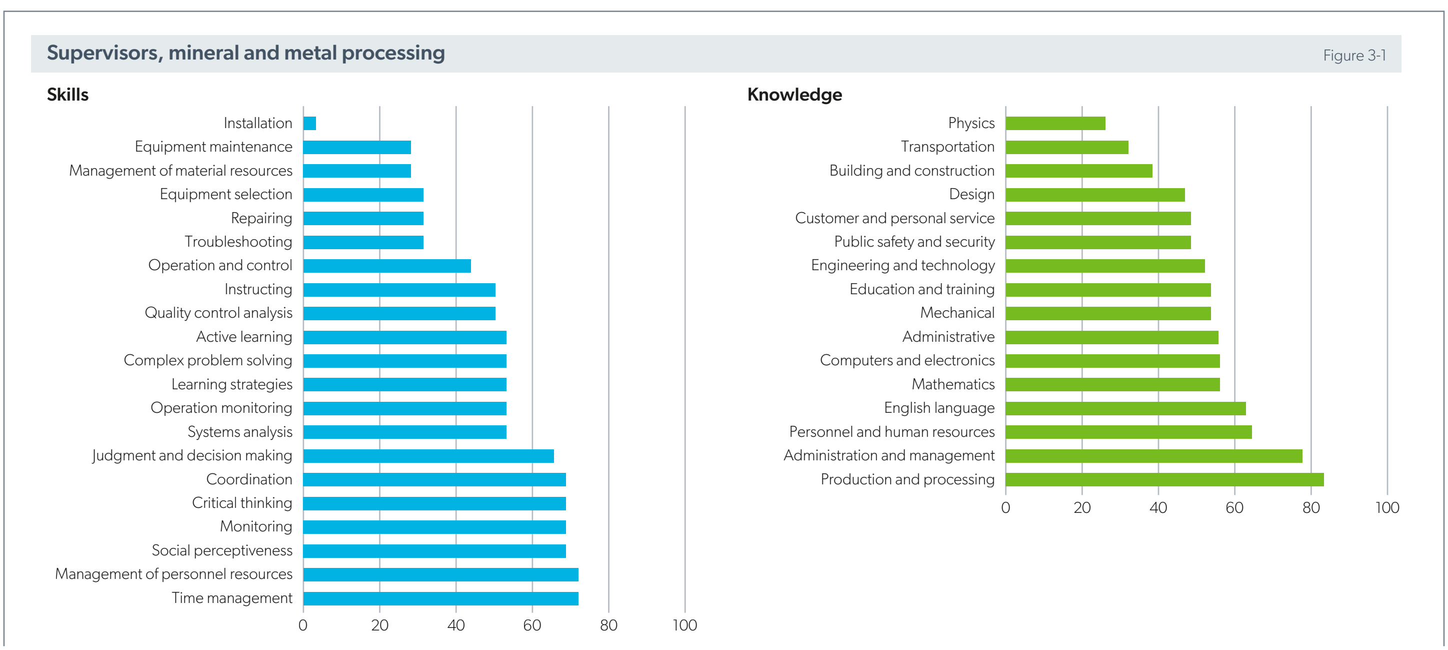
Skills	
Critical thinking	56.58
Monitoring	54.33
Operations monitoring	52.46
Judgment and decision making	50.19
Time management	50.16
Coordination	49.93
Complex problem solving	49.01
Operation and control	47.37
Social perceptiveness	46.89
Quality control analysis	44.89

Knowledge	
English language	55.82
Mathematics	52.39
Mechanical	52.36
Production and processing	51.69
Administration and management	47.12
Customer and personal service	45.10
Public safety and security	44.78
Education and training	43.29
Computers and electronics	39.91
Engineering and technology	36.98

Table 5 shows the ten skills and knowledge attributes most found among the primary metal manufacturing workforce, along with the weighted importance of these skills to non-metallic mineral product manufacturing workers on a scale of 1-100.

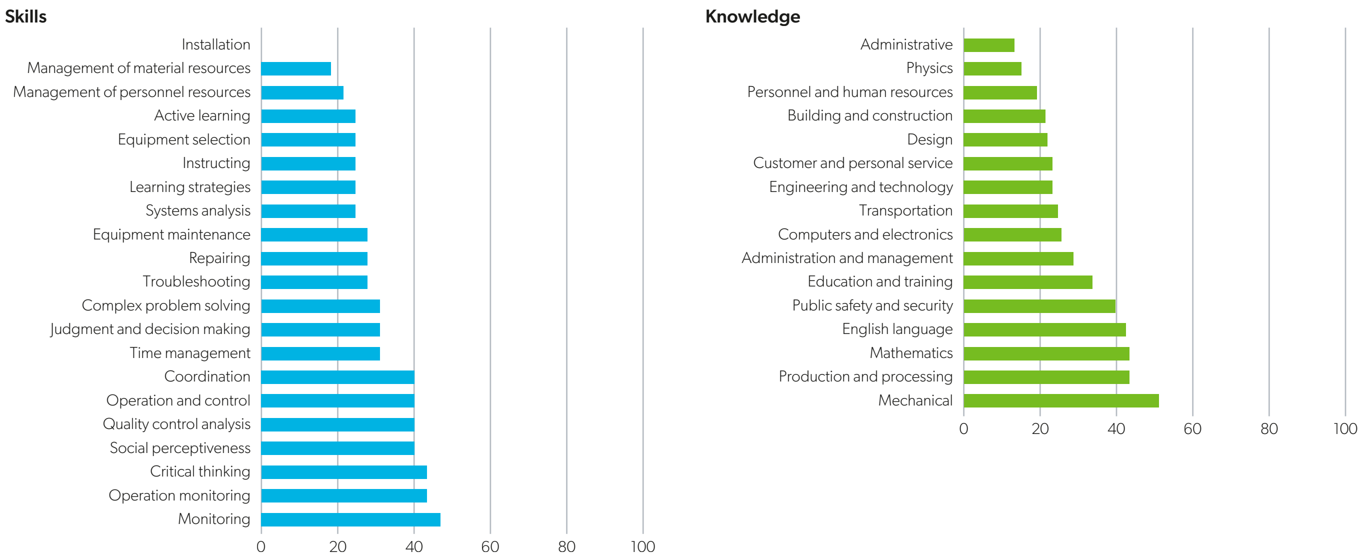
Within operator roles, resource management skills, like management of material and personnel resources, and quality control are important for machine operators. Specifically, crane operators require higher levels of technical skills such as operation and control, operations monitoring, repairing, and troubleshooting, alongside a greater importance for active learning. While production and processing knowledge is of relatively high importance for all selected occupations, it is highest for supervisors and machine operators. In contrast, critical thinking is most important for mineral and metal processing supervisors. For construction millwrights, technical skills like installation, operation monitoring, equipment maintenance and quality control analysis have the highest importance. For knowledge requirements, construction millwrights require higher levels of engineering and science knowledge such as building and construction, mechanical knowledge, physics, and mathematics.

Figure 3. Current skills and knowledge needed by workers in primary metal manufacturing (absolute scores, 0–100)



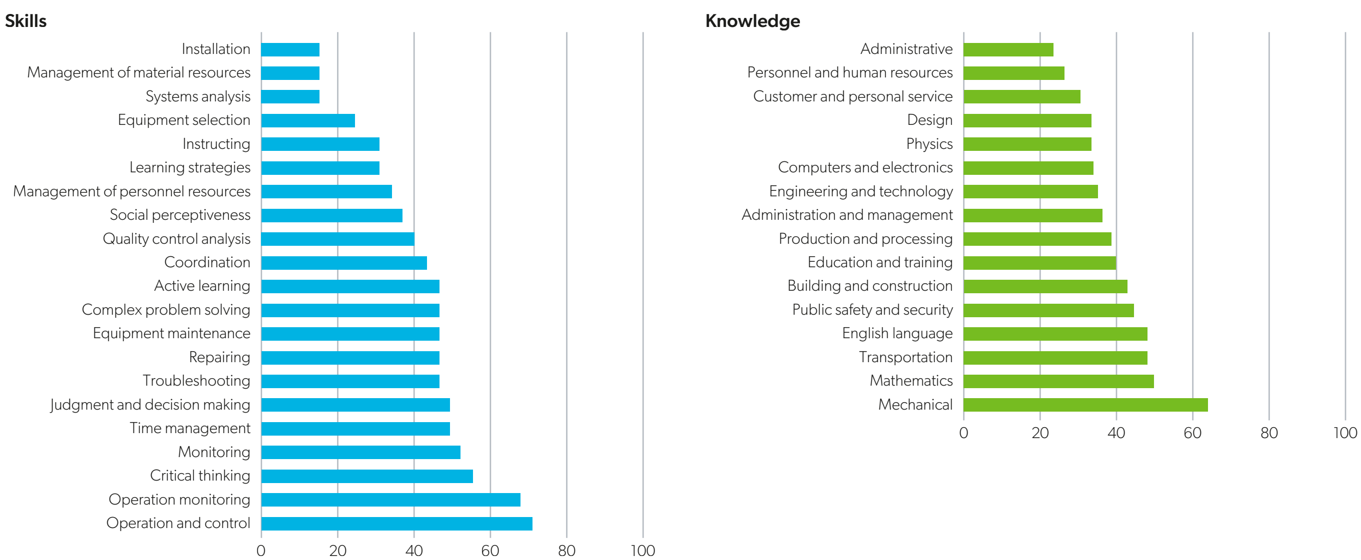
Labourers, mineral and metal processing

Figure 3-2



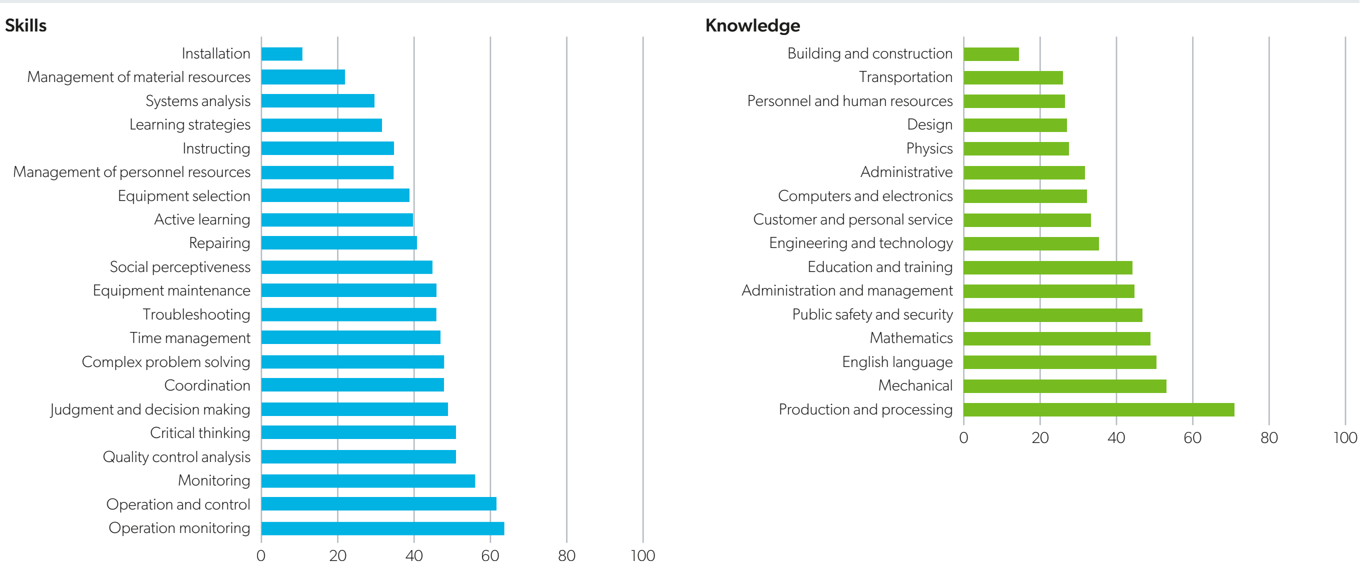
Crane operators

Figure 3-3



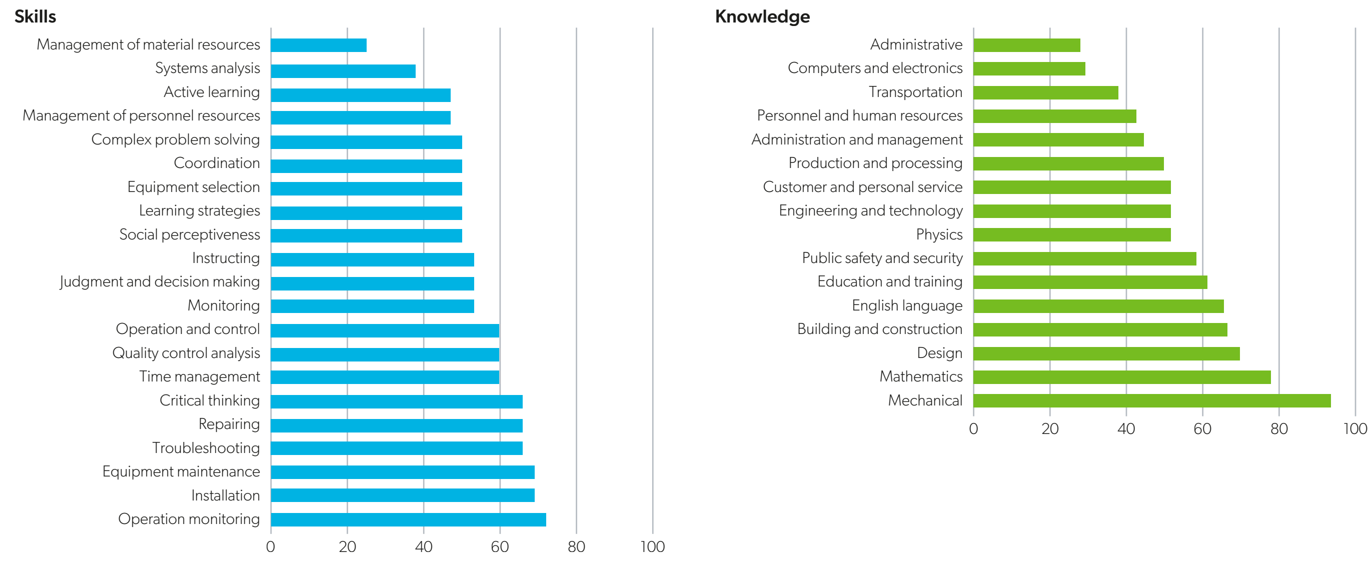
Machine operators, mineral and metal processing

Figure 3-4



Construction millwrights and industrial mechanics

Figure 3-5



Future skills needs

This sub-sector is involved in the raw materials part of the supply chain, whereby establishments produce pig iron and convert it into steel. Companies may produce metal ingots or iron and steel-based shapes such as plates, sheets, strips, rods, and bars.[52] In the shift to ZEVs, advanced high-strength or ultra-high strength steel is needed to minimize weight within the vehicles to achieve a high range for a given battery size and weight.[53] Therefore, advanced high-strength or ultra-high strength steel is a top material of choice among engineers and designers for ZEVs.[54] When creating steel-based shapes, the shift from mild traditional steel to high-strength or ultra-high strength steel requires different processes and equipment, primarily due to the additions of different alloying elements, the degree of mechanical manipulation, and the thermal treatment process.[55] High-strength steel requires different resistance spot welding, metal inert gas welding, and brazing processes than mild steel, and the recommended joint configurations, riveting methods, transfer methods, heat applications, wire speeds, and voltage settings are also much different than those used on mild steel.[56]

For workers, these changes will require specific chemical and mechanical knowledge. Those who create iron or steel-based shapes will need technical skills to use the equipment to work with the metals correctly. Lower-skilled jobs, such as labourers and machine operators, may be partially replaced by higher-skilled jobs, such as engineers, technologists, and technicians, that will be needed to work on new products and implement process improvements.[57] These occupations are associated with skills in and knowledge of computer-controlled tools, robotics, and manufacturing software, such as computer-aided design and computer-aided manufacturing.[58]

Our foresight analysis from our survey of industry stakeholders identified a number of skills and knowledge pieces that would be the most in demand for occupations in the PM manufacturing sub-sector. Construction millwrights and industrial mechanics were identified by a little less than half (42%) of respondents as one of the jobs they expected to be the most in demand by 2030. The skills and knowledge pieces expected to be the most in demand for these jobs in the future are communications (reading, writing, active listening, and team monitoring), critical thinking, and operations monitoring skills, alongside knowledge in production and processing as well as computers and electronics knowledge. Additionally, more than a third of respondents (42%) expected plant supervisors to be in high demand in the future. The skills expected by respondents to be in future high demand for this occupation are critical thinking, operations monitoring, and communications (reading, writing, active listening, and team monitoring). A small minority of respondents (21%) also thought general machinists would be an occupation in future high demand. For general machinists, the skills and knowledge pieces respondents expected to be in high demand in the future are mechanical, mathematical, and production knowledge, alongside critical thinking and operations monitoring skills.

Plastics and rubber production manufacturing

In this report, industries represented in plastics and rubber production manufacturing are Plastic product manufacturing (NAICS 3261) and Rubber product manufacturing (NAICS 3262). This sub-sector comprises establishments primarily engaged in making goods by processing raw rubber and plastics. This sub-sector employed 48,625 people in Ontario in 2021, a 21.7% increase from the previous year. Ontario's employment in this sub-sector accounted for more than half (51.4%) of employment in Canada's plastics and rubber products manufacturing sector. Toronto accounts for most of the employment in this sub-sector (38.5%), followed by Kitchener-Waterloo-Barrie (30%).[59] Women accounted for 35.3% of the sub-sector's employment in 2021, which is higher than the female representation in the manufacturing sector as a whole.[60] Older workers (aged 55+) comprised 25.2% of the sub-sector.[61] Key occupations in plastics and rubber production for ZEV manufacturing are supervisors in plastic and rubber products manufacturing, labourers in rubber and plastic products manufacturing, mixing machine operators for plastics processing, calendering process operators for plastics processing, and extruding process operators for plastics processing.

Current workforce profile

Individuals involved in plastics and rubber product manufacturing have strong critical thinking, monitoring, and time management skills, while quality control analysis remains less important. Workers in this sub-sector also have strong expertise in the English language, production and processing knowledge, and knowledge and application of mathematics. Administrative knowledge and knowledge in education and training is still important, but comparatively less so for workers in the plastics and rubber product manufacturing sub-sector, relative to other parts of the ZEV supply chain.

Across all selected occupations in this sub-sector, technical skills such as operations monitoring and operation and control are highly important, particularly for operator roles. Supervisors and management roles require higher levels of basic process skills such as critical thinking, active learning, learning strategies, and monitoring, in addition to management skills. Operator roles require technical skills related to operations, troubleshooting, and quality control analysis. Production and processing knowledge is of high importance across all selected occupations, particularly for supervisors and mixing machine operators. Within operator roles, knowledge requirements vary, with mathematics knowledge being more important for mixing machine operators and extruding process operators than for calendering process operators. Calendering process operators, in turn, require higher transportation knowledge. The importance of the English language knowledge is highest for supervisors and extruding process operators.

Table 6. Summary of top weighted-average skills and knowledge importance scores in plastics and rubber manufacturing

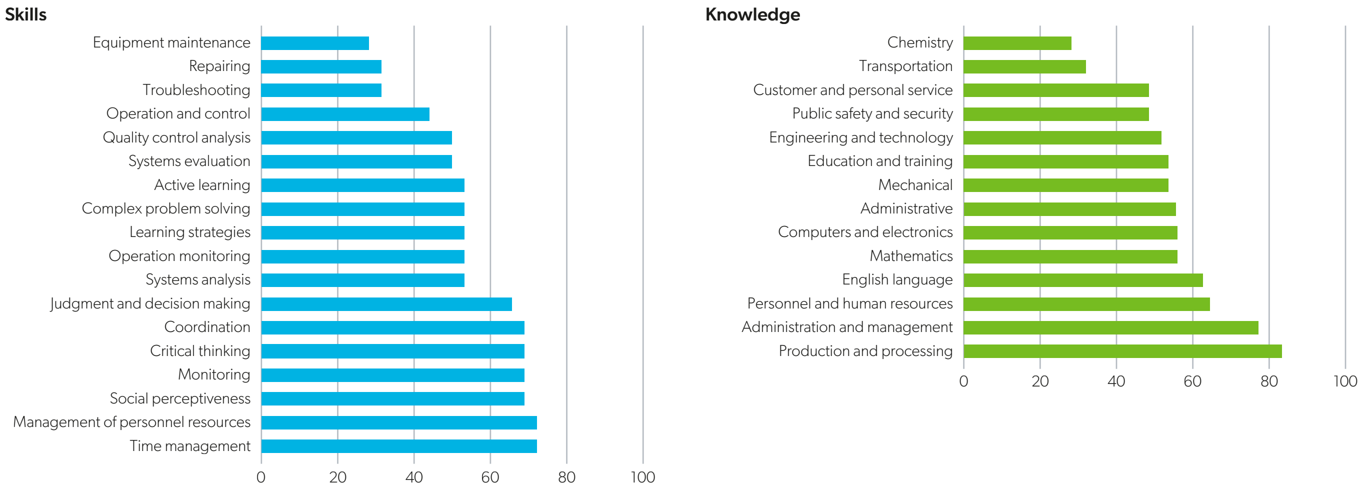
Skills	
Critical thinking	56.25
Monitoring	54.44
Time management	51.77
Operations monitoring	51.46
Judgment and decision making	51.12
Coordination	50.88
Complex problem solving	49.28
Social perceptiveness	48.96
Operation and control	46.01
Quality control analysis	44.94

Knowledge	
English language	58.86
Production and processing	57.44
Mathematics	52.74
Customer and personal service	49.90
Mechanical	46.37
Administration and management	46.04
Public safety and security	43.18
Computers and electronics	41.37
Education and training	39.53
Administrative	38.96

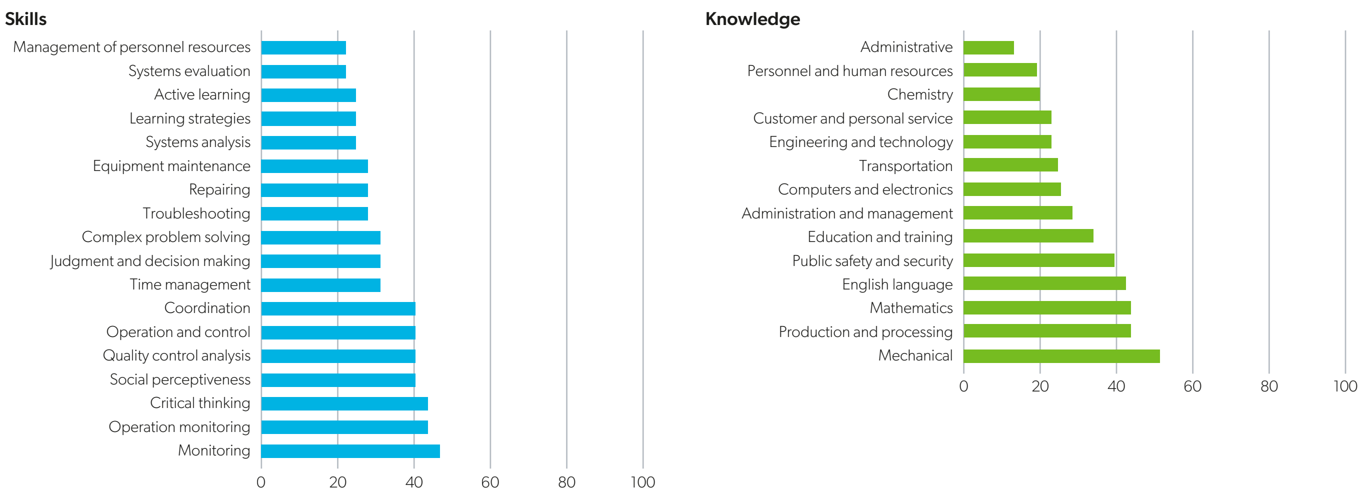
Table 6 shows the ten skills and knowledge attributes most found among the plastics and rubber manufacturing workforce, along with the weighted importance of these skills to non-metallic mineral product manufacturing workers on a scale of 1-100.

Figure 4. Current skills and knowledge needed by workers in plastics and rubber product manufacturing (absolute scores, 0–100)

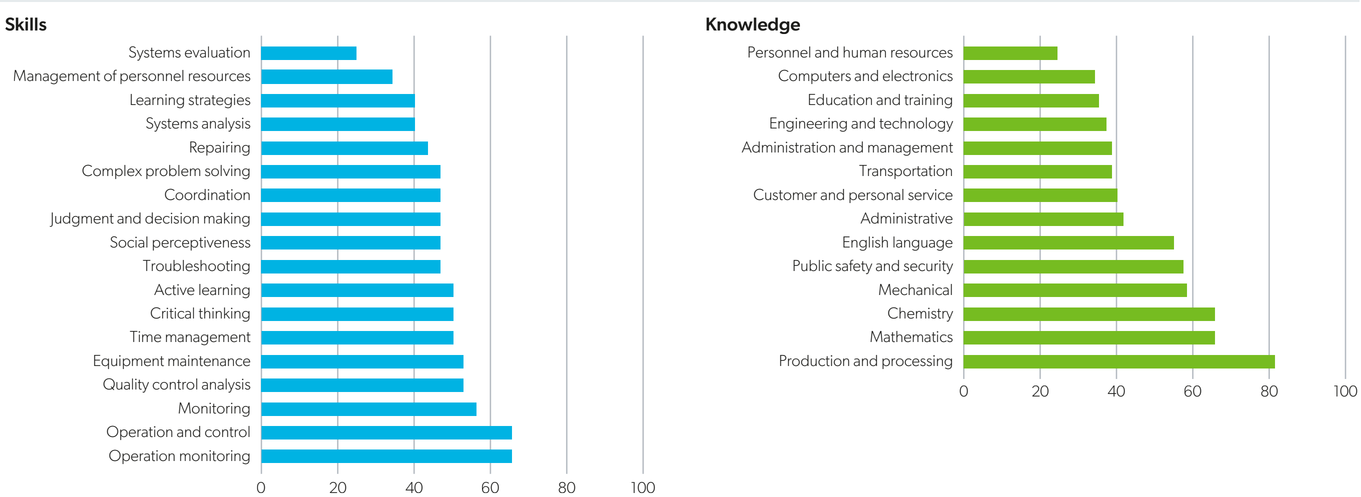
Supervisors, plastic and rubber products manufacturing Figure 4-1



Labourers, plastic and rubber products manufacturing Figure 4-2

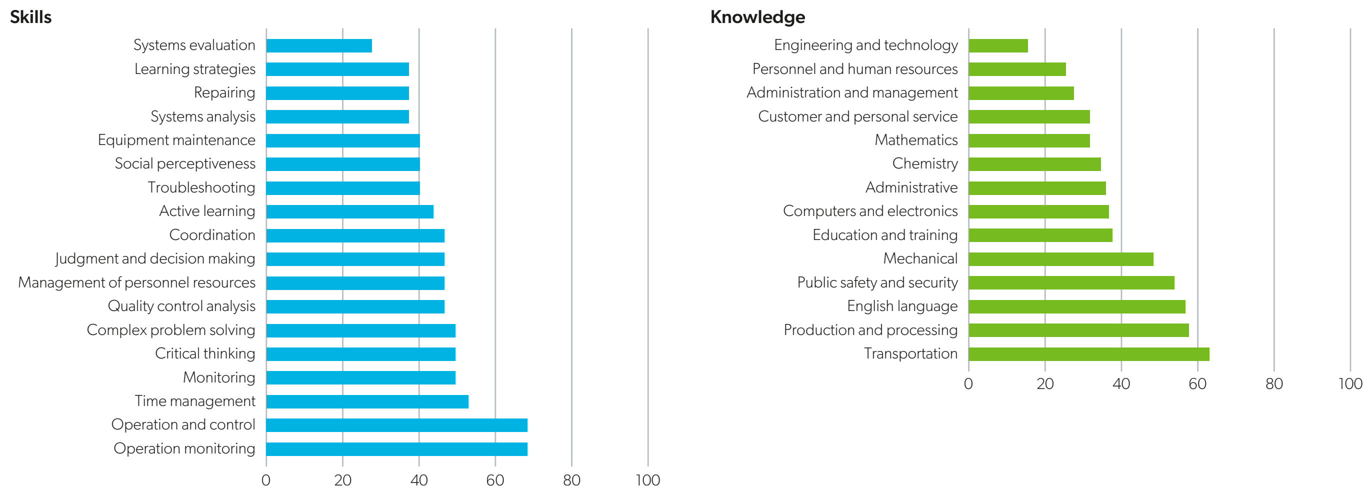


Mixing machine operators, plastics processing Figure 4-3



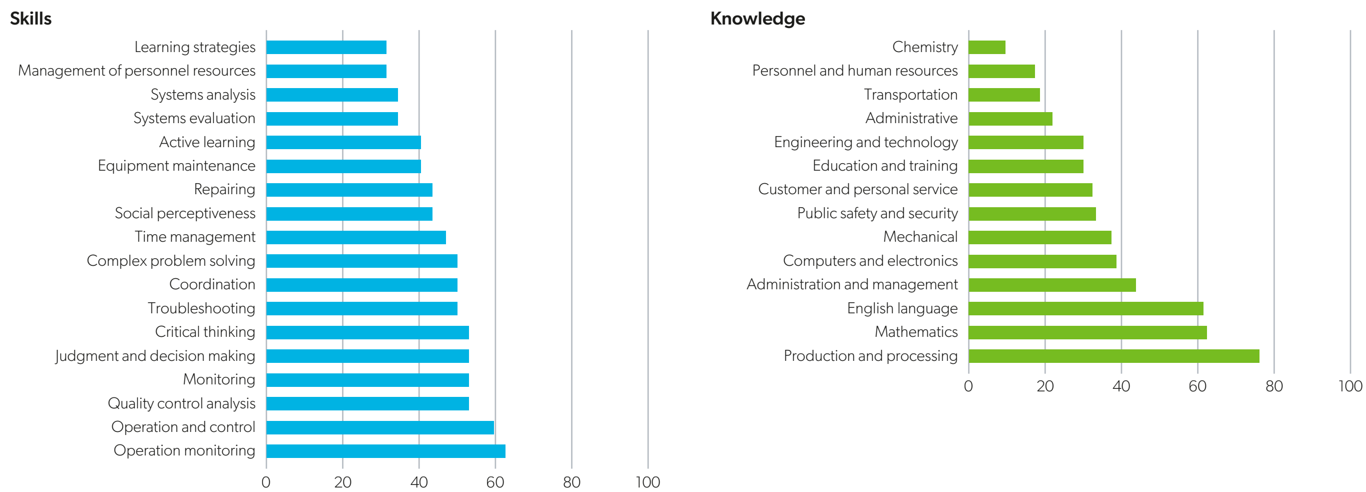
Calendering process operators, plastics processing

Figure 4-4



Extruding process operators, plastics processing

Figure 4-5



Future skills needs

This part of the sub-sector is involved in producing the Tier 2 sub-components of the ZEV supply chain by processing raw rubber and plastics materials.[62] Overall, the shift from the ICEV to ZEV is expected to lead to about a 30% reduction in the quantity of plastics used in a vehicle. This change will not affect plastics used in products like interior trim, side doors, seat belts, and front and rear bumpers, but rather for plastics used in fuel tanks, engine covers, air-intake manifolds, and reservoirs.[63] New areas of growth in plastics for auto manufacturing will emerge around battery packs and power electronics given that inverters, converters, and onboard chargers all need plastic housings.[64] Many manufacturers are turning to advanced polymer solutions for plastic housings for batteries and power electronics, integrating the value of materials such as silicone, polyurethane, and acrylic to reduce operating temperatures.[65] For rubber, uses will remain mostly similar, albeit with a few differences. Rubber is currently used in tires, rubber pads on pedals, rubber mouldings in car engines, hoses, timing belts, seals, and gaskets, and will continue to be used for many of these components, although some will not remain in use with the transition to ZEVs. However, changes will emerge from the absence of certain components (such as timing belts and engines) and from ZEV tires being designed to withstand additional weight, dynamic loading, and tractive demands, among other things.

Those working with rubber will not be greatly affected by the shift from ICEVs to ZEVs in terms of skills and knowledge requirements. For most workers, the greatest knowledge shift will be the need to work with new tire models. For those working with plastics however, higher levels of chemical and material knowledge will be required for creating new plastics, along with material handling skills to turn them into housings. Higher-skilled jobs involving digital operations, advanced production, and operational management will increasingly become desirable, along with skills in technology and programming related to automation, problem solving, and mathematics. Demand for occupations such as data analysis, artificial intelligence and machine learning specialists, and software and application developers will grow. For factory floor workers, hands-on skills need to be accompanied by more specialised digital skills, such as the ability to work with a particular computer numerical control machine model, that will continue to evolve.[66]

From our survey of industry stakeholders, a few occupations in the plastics and rubber production manufacturing sub-sector are expected to be in high demand in the future, along with some skills and knowledge pieces for these respective occupations. More than a third of respondents (42%) expected plant supervisors to be in high demand in the future.[67] The skills expected by respondents to be in future high demand for this occupation are critical thinking, operations monitoring, and communications (reading, writing, active listening, and team monitoring). A small minority of respondents (21%) also thought machinists would be an occupation in high demand in the future. For machinists, the skills and knowledge pieces respondents expected to be in high demand in the future are mechanical, mathematical, and processing and production knowledge, alongside critical thinking and operations monitoring skills.

Non-metallic mineral product manufacturing

In this report, the industry represented in non-metallic mineral product manufacturing is Glass and glass product manufacturing (NAICS 3272). This sub-sector comprises establishments primarily engaged in manufacturing non-metallic mineral products. Among other things, these establishments heat non-metallic mineral preparations to make products, such as glass.[68] The non-metallic mineral product manufacturing industry employed 21,455 workers in Ontario in 2017,[69] the biggest employer in this industry of all the provinces. This is largely due to the presence of a significant downstream manufacturing industry in Ontario, particularly focused in the Toronto, Hamilton-Niagara Peninsula, and Kitchener-Waterloo-Barrie economic regions.[70] Similar to other sectors in this report, there is low representation of women in the workforce. Key occupations in non-metallic mineral product manufacturing for auto and ZEV manufacturing are manufacturing managers, industrial instrument technicians and mechanics, labourers in mineral and metal processing, industrial engineering and manufacturing technologists, and glass process control operators.

Current workforce profile

Individuals involved in non-metallic mineral product manufacturing have strong critical thinking, monitoring, and complex problem solving skills, while operation and control remains less important. Workers in this sub-sector have strong expertise in the English language, computers and electronics, and production and processing. Knowledge in administration and management remains important, but comparatively less so for workers in the non-metallic mineral product manufacturing sub-sector.

For industrial instrument technicians and mechanics, technical skills are the most important, particularly operations monitoring, quality control analysis, and repairing. Comparatively, industrial engineering and manufacturing technologists require higher levels of systems skills, such as judgment and decision making, systems analysis, and systems evaluation. Complex problem solving is more important for both of these occupations than the other occupations selected. Workers in this sub-sector require engineering and technology, computers and electronics, design, mechanical, and mathematics knowledge. This knowledge is particularly important for industrial instrument technicians and mechanics, as well as glass process control operators. Manufacturing managers' knowledge profile leans more towards administration, customer and personal service, and personnel and human resources.

Table 7. Summary of top weighted-average skills and knowledge importance scores in non-metallic mineral products

Skills	
Critical thinking	61.67
Monitoring	57.21
Complex problem solving	56.48
Operations monitoring	55.93
Time management	53.58
Judgment and decision making	52.44
Coordination	52.18
Quality control analysis	51.19
Active learning	49.05
Operation and control	47.90

Knowledge	
English language	61.96
Computers and electronics	56.26
Production and processing	53.68
Mathematics	53.62
Customer and personal service	53.03
Mechanical	48.71
Public safety and security	47.97
Engineering and technology	46.05
Administration and management	45.24
Administrative	42.91

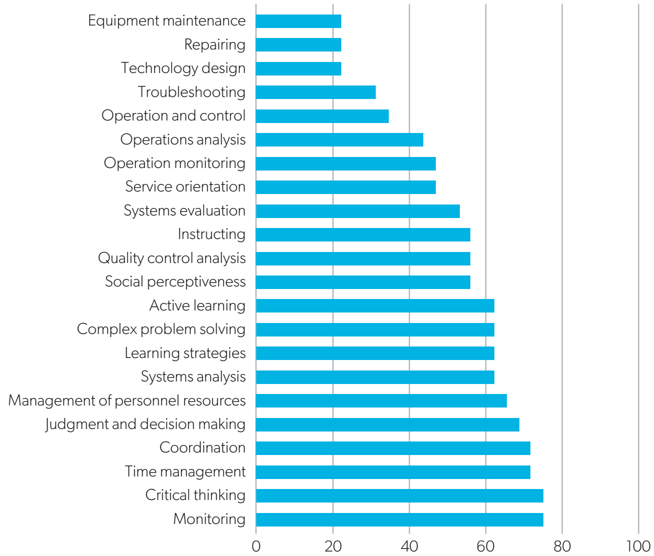
Table 7 shows the ten skills and knowledge attributes most found among the non-metallic mineral product manufacturing workforce, along with the weighted importance of these skills to non-metallic mineral product manufacturing workers on a scale of 1-100.

Figure 5. Current skills and knowledge needed by workers in non-metallic mineral product manufacturing (absolute scores, 0–100)

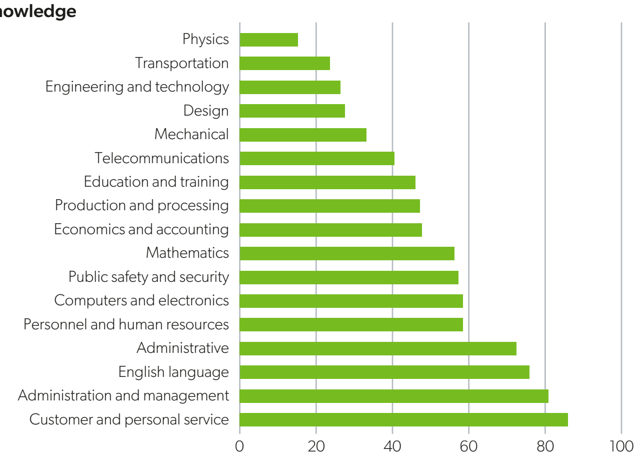
Manufacturing managers

Figure 5-1

Skills



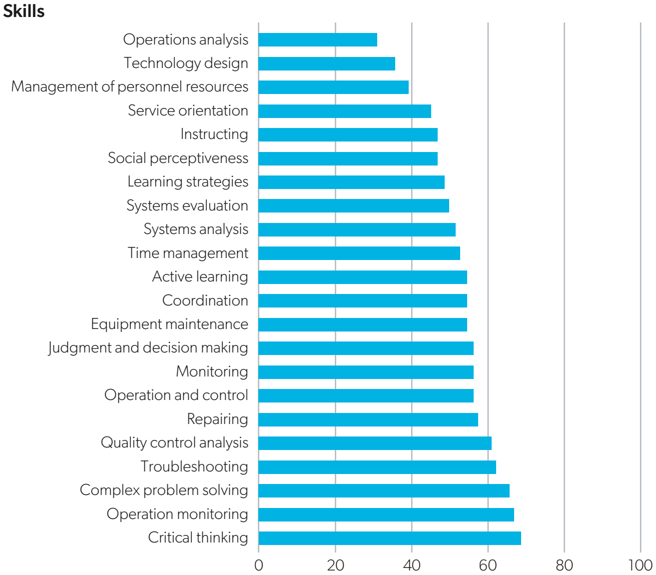
Knowledge



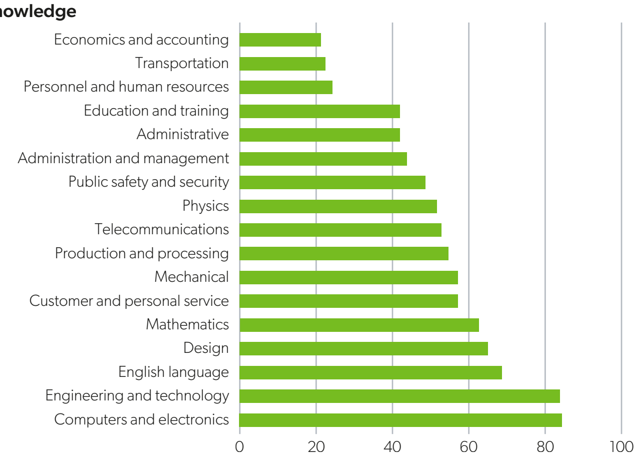
Industrial instrument technicians and mechanics

Figure 5-2

Skills



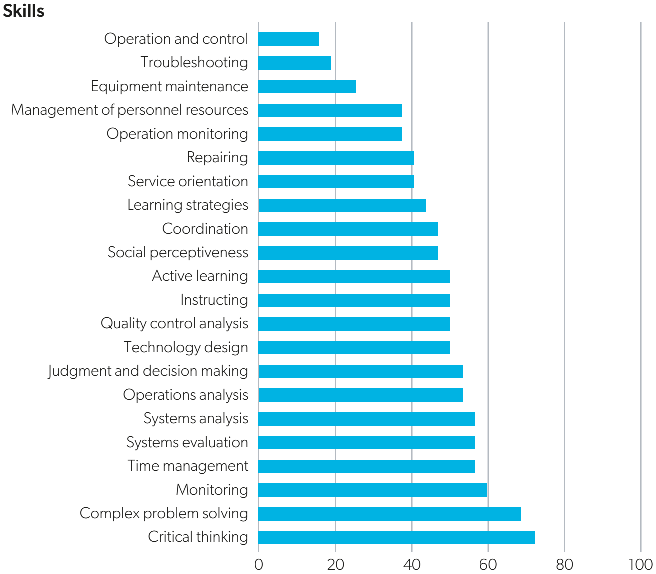
Knowledge



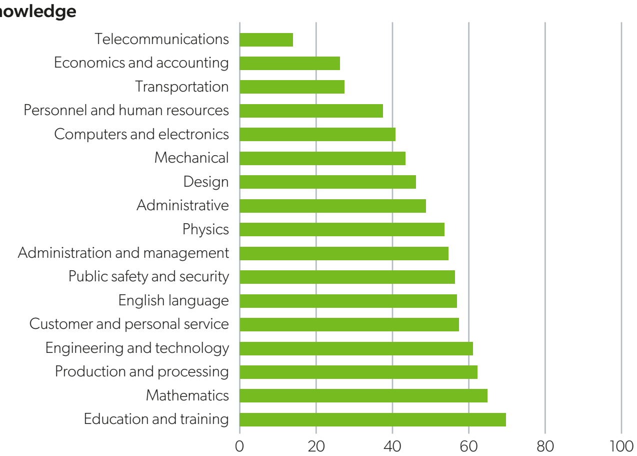
Industrial engineering and manufacturing technologists

Figure 5-3

Skills

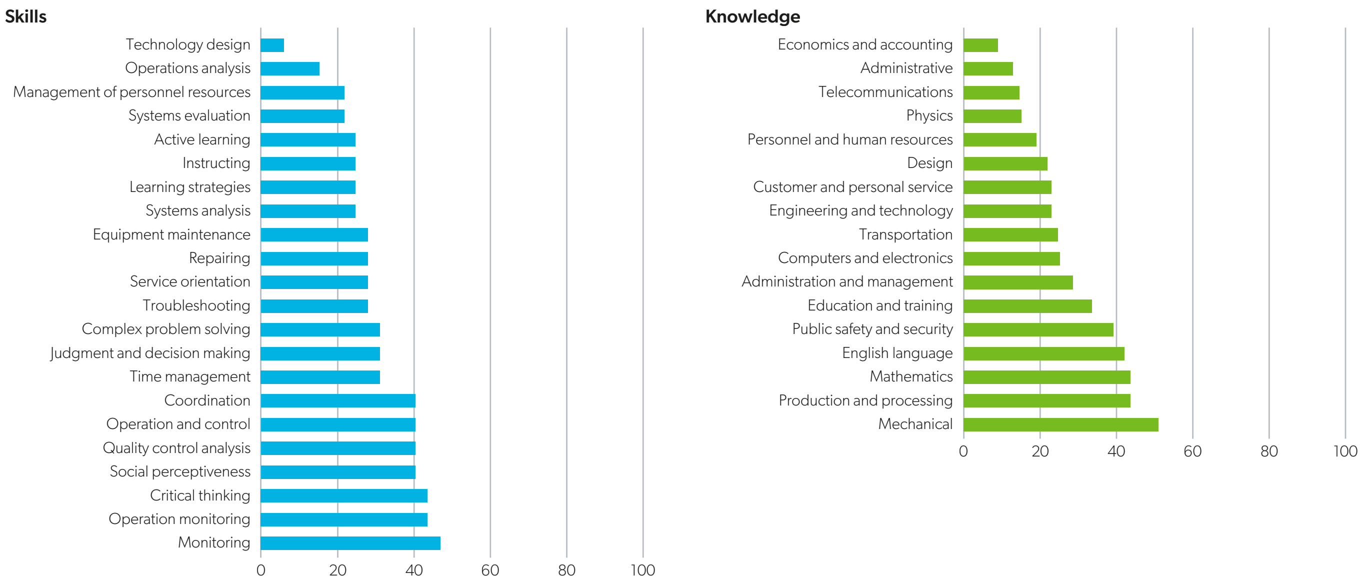


Knowledge



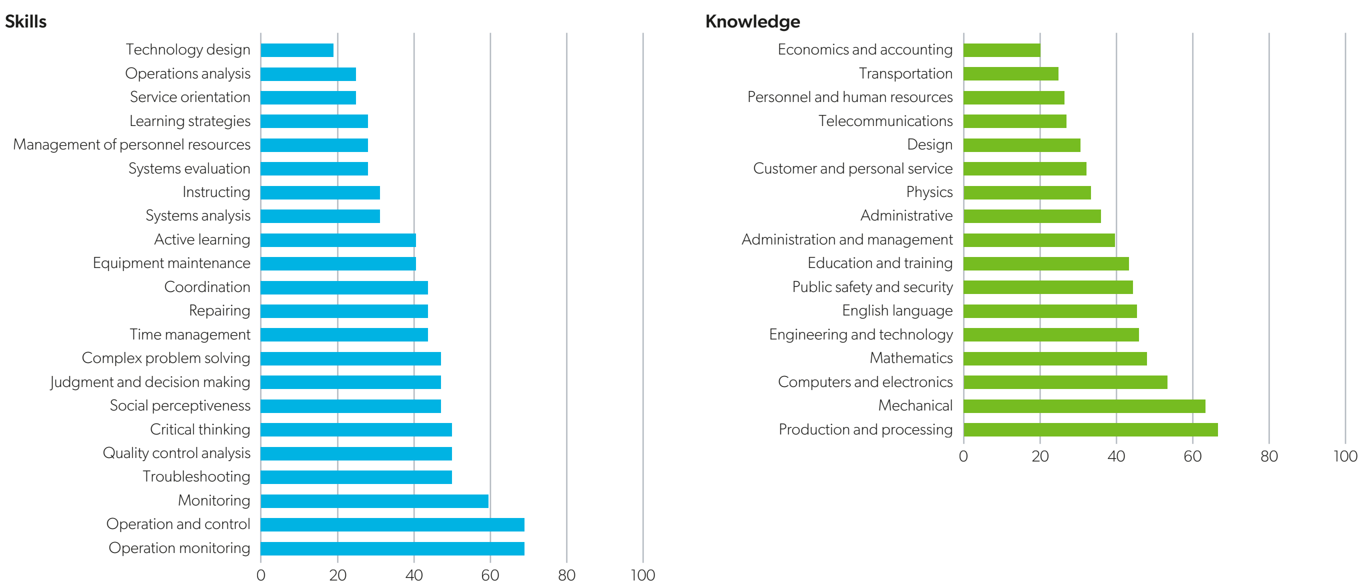
Labourers in mineral and metal processing

Figure 5-4



Glass process control operators

Figure 5-5



Future skills needs

This part of the sub-sector is involved in producing the Tier 2 sub-components of the ZEV supply chain by heating non-metallic mineral preparations to make products (specifically glass in this report).[71] Most glass used for vehicles is auto glass used for windows or windshields. This is not expected to change between ICEVs and ZEVs, meaning this sub-sector and its workers should not require skills and knowledge changes in the near term. In the longer term, with increased automation, lower-skilled jobs, such as labourers and machine operators, may need to upskill to work with computer-controlled tools, robotics, and manufacturing software — or risk being at least partially replaced by jobs at higher skill levels, such as engineers, technologists, and technicians.

Our foresight analysis from our survey of industry stakeholders identified a number of skills and knowledge pieces that were expected to be the most in demand for occupations in the computer and electronic manufacturing sector. A little less than half (42%) of respondents identified construction millwrights and industrial mechanics as one of the jobs they expected to be the most in demand by 2030. The skills and knowledge pieces expected to be the most in demand for this job in the future are communications (reading, writing, active listening, and team monitoring), critical thinking, and operations monitoring skills, alongside knowledge in production and processing as well as computer and electronics.

Fabricated metal product manufacturing

In this report, the industries represented in non-metallic mineral product manufacturing are Architectural and structural metals manufacturing (NAICS 3323) and Machine shops, turned product, and screw, nut and bolt manufacturing (NAICS 3327). This sub-sector comprises establishments primarily engaged in forging, stamping, forming, turning, and joining processes to produce metal products such as structural metal products, hardware, springs and wire products, turned products, and bolts and screws.[72] Ontario is a hub for the fabricated metal product manufacturing industry in Canada, employing 66,536 workers and accounting for 43.1% of the national workforce.[73] The majority of workers in this sub-sector are employed in architectural and structural metals manufacturing (28.8%), followed by machine shops, turned product, and screw, nut and bolt manufacturing (21.1%). In Ontario, nearly one-third of the fabricated metal product manufacturing employment was in the Toronto economic region. The Hamilton-Niagara Peninsula and Kitchener-Waterloo-Barrie economic regions each represented 19.9% of provincial employment in this subsector in 2021. The industry is male-dominated, with men representing almost four in five workers in Ontario in 2021, while workers aged 55 years and above made up over a quarter of employment in the industry in Ontario.[74]

Key occupations in fabricated metal product manufacturing for ZEVs and batteries are machinists, manufacturing managers, supervisors of other mechanical and metal products manufacturing, labourers in metal fabrication, and welders.

Current workforce profile

Critical thinking, monitoring, and coordination skills are important for individuals involved in fabricated metal product manufacturing, while quality control analysis remains less important. Workers in this sub-sector have strong expertise in mathematics, the English language, production and processing, and mechanical knowledge. Knowledge in engineering and technology as well as computers and electronics are still important, but comparatively less so for workers in this sub-sector.

Across the selected occupations in this sub-sector, basic process skills are of high importance, such as active learning, critical thinking, monitoring, and learning strategies. These skills are particularly important for manufacturing managers and supervisors. Social skills like coordination and social perceptiveness are also important. While systems skills and judgment and decision making have higher importance for managerial occupations, technical skills like operations monitoring and control, as well as quality control analysis, are of relatively higher importance for labourers, welders, and machinists presently. Manufacturing managers and supervisors have roles that require higher levels of customer and personal service, administration and management, and English language knowledge. Comparatively, for labourers, welders, and machinists, mathematics, production and processing, and mechanical knowledge are the most important. Machinists have the highest importance scores for this knowledge, alongside high importance for knowledge in design as well as engineering and technology. Supervisors have the highest requirement for production and processing knowledge out of the selected occupations.

Table 8. Summary of top weighted-average skills and knowledge importance scores in fabricated metal and product manufacturing

Skills	
Critical thinking	58.37
Monitoring	56.71
Coordination	52.62
Time management	52.51
Complex problem solving	51.36
Judgment and decision making	51.10
Operations monitoring	50.41
Social perceptiveness	49.11
Active learning	45.84
Quality control analysis	45.72

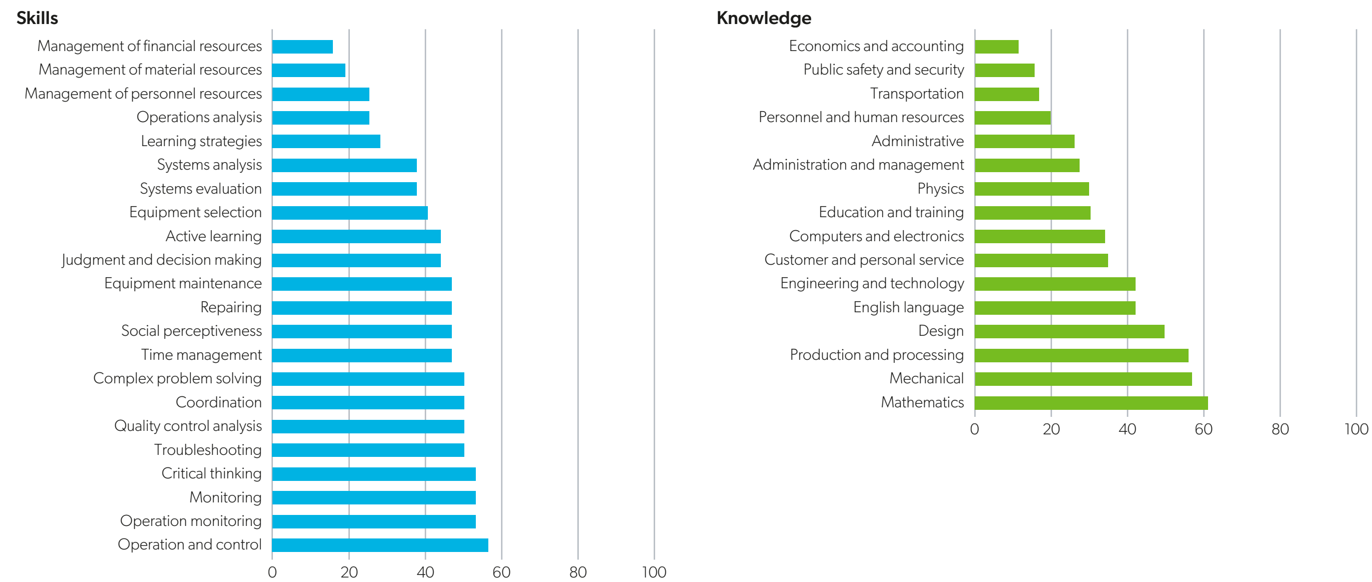
Knowledge	
Mathematics	56.47
English language	55.50
Production and processing	55.05
Mechanical	51.94
Administration and management	48.96
Customer and personal service	48.25
Education and training	42.11
Design	41.26
Computers and electronics	40.29
Engineering and technology	39.68

Table 8 shows the ten skills and knowledge attributes most found among the fabricated metal product manufacturing workforce, along with the weighted importance of these skills and knowledge attributes to fabricated metal product manufacturing workers on a scale of 1-100.

Figure 6. Current skills and knowledge needed by workers in fabricated metal product manufacturing (absolute scores, 0–100)

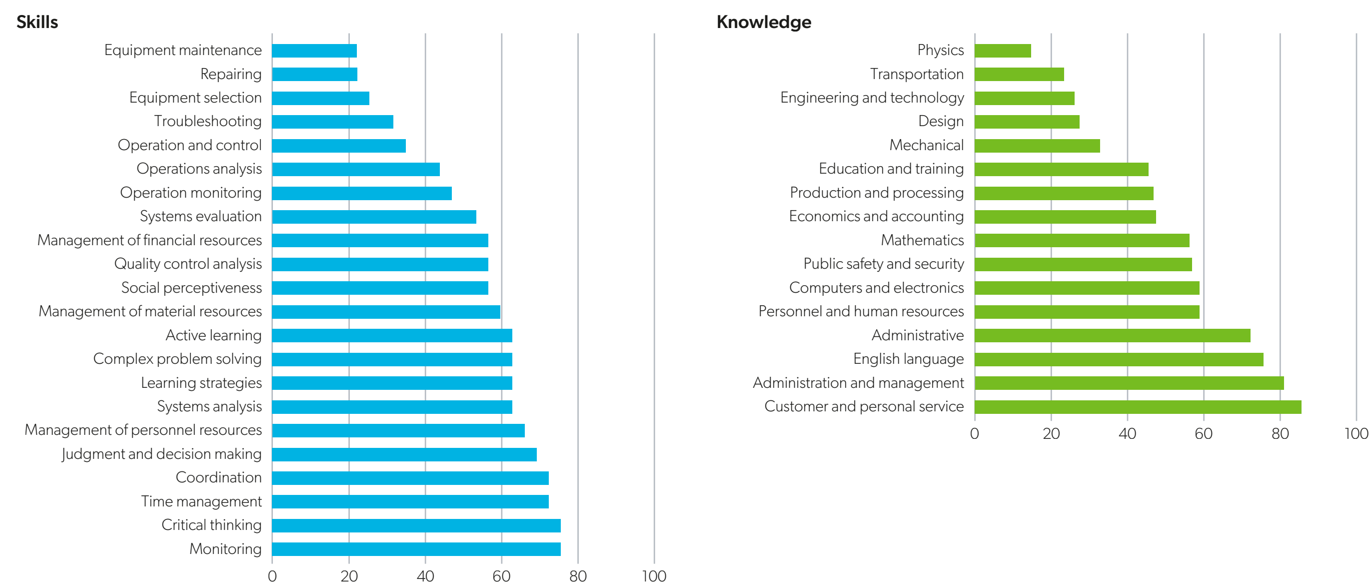
Machinists

Figure 6-1



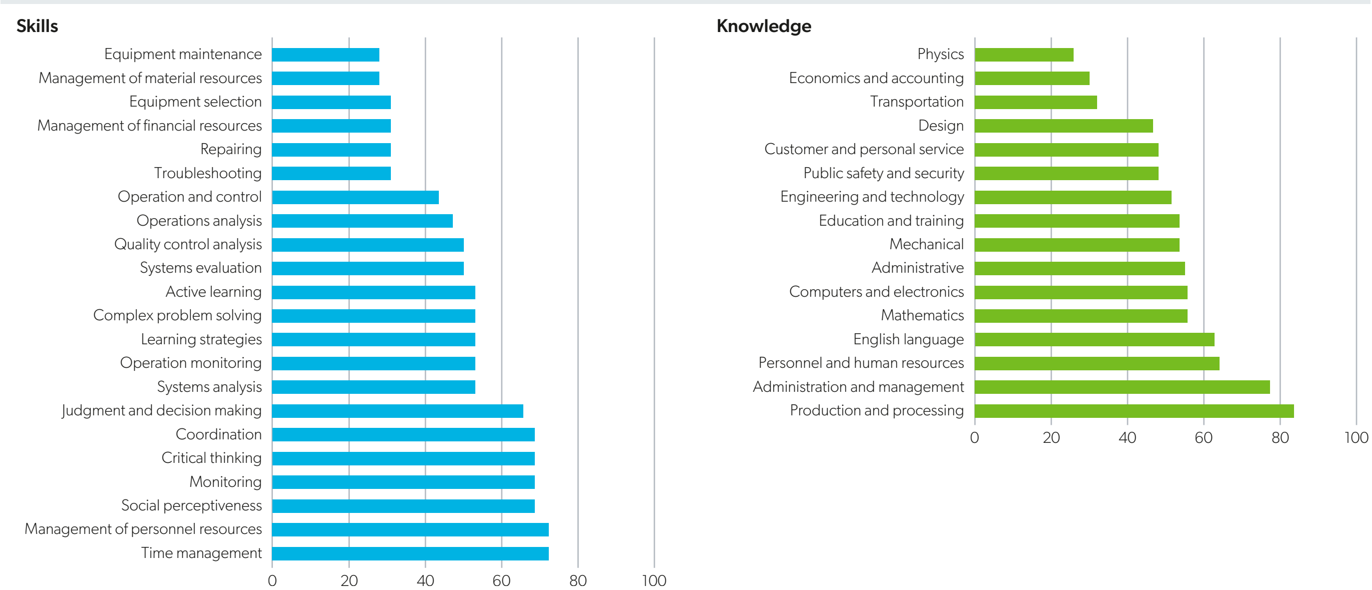
Manufacturing managers

Figure 6-2



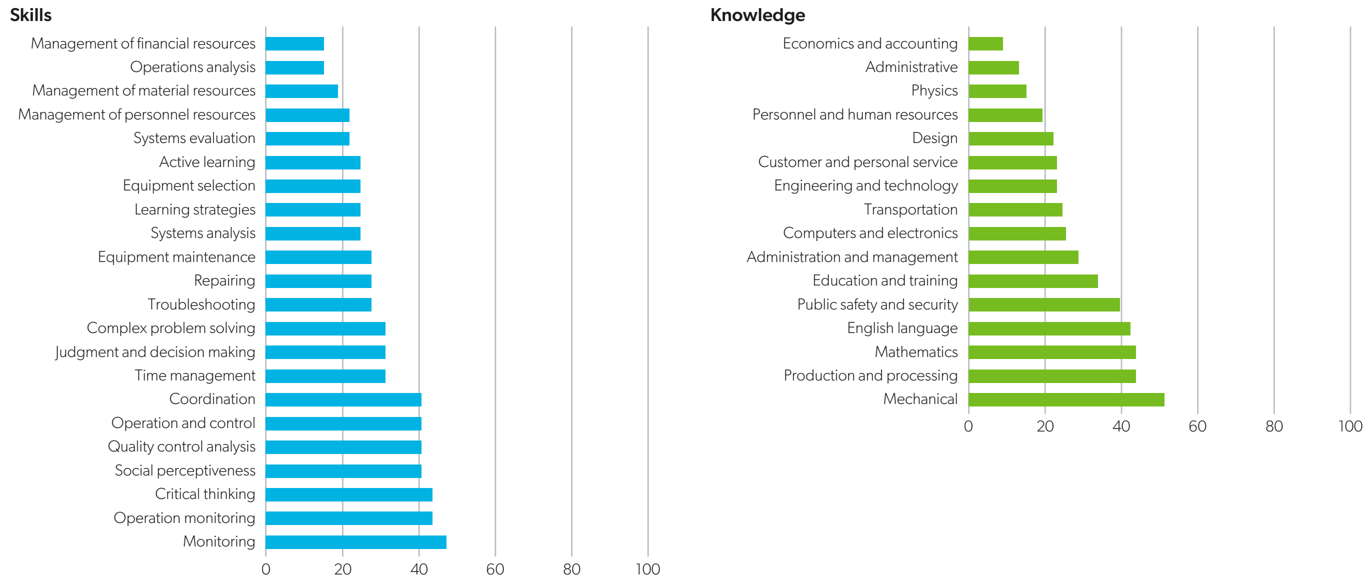
Supervisors, other mechanical and metal products manufacturing

Figure 6-3



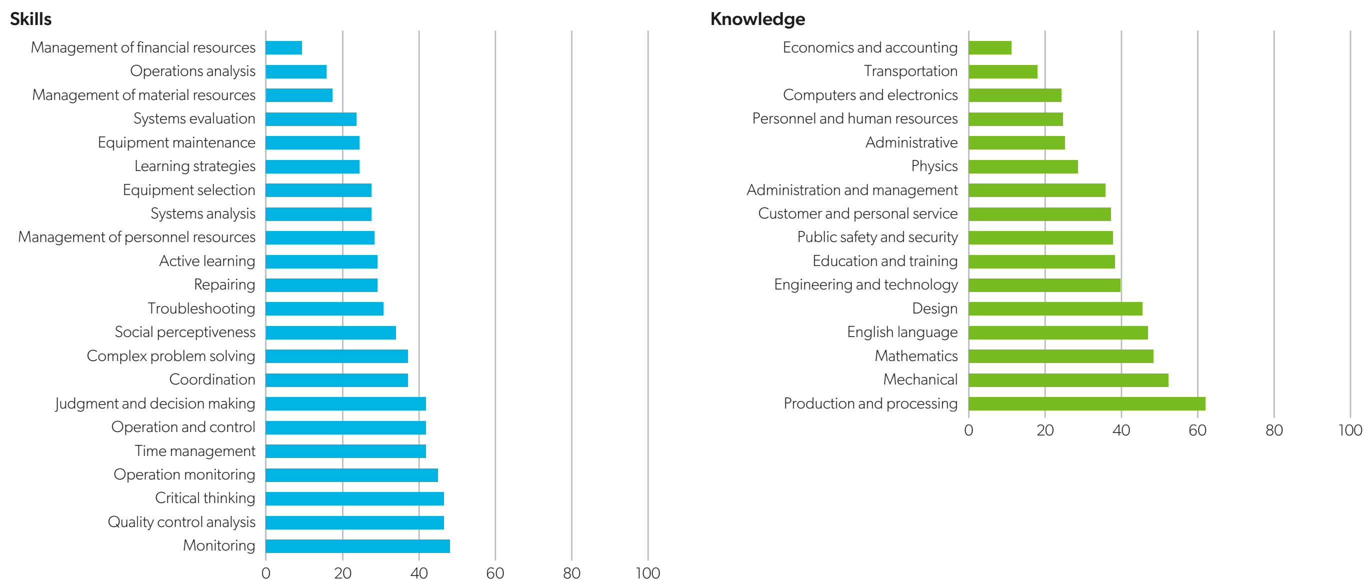
Labourers in metal fabrication

Figure 6-4



Welders

Figure 6-5



Future skills needs

This part of the sub-sector is involved in producing the Tier 2 sub-components of the ZEV supply chain by using forging, stamping, forming, turning, and joining processes to produce metal products, such as structural metal products, and fastenings, like bolts, nuts, and screws.[75] These products are used throughout the vehicle, from the internal workings to the body, trim, and interior. For ZEVs, two demands will drive change within this sub-sector. The first is lightweighting, as vehicle bodies need to be lighter.[76] The second is the need for certain components to be conductive, while others will need to be isolated for safety reasons.[77] Additionally, new challenges are being created as manufacturers move away from using standard steel in motor housings, as previously identified, to different materials like high-strength steel, aluminum, and plastics, which require fastener solutions to handle different temperature and tolerance demands.[78]

For the workforce, increased engineering, design, and production and processing expertise will be needed alongside electrical and fire safety knowledge to manufacture ZEV-grade fasteners for use throughout the vehicle. Higher-skilled occupations, such as mechanical engineers, industrial and manufacturing engineers, and computer programrs, will be in demand, associated with skills like programming, technical or technological design, problem solving, decision making, and critical thinking. Workers will increasingly require knowledge of numerical tools, robotics, and manufacturing software.

From our survey of industry stakeholders, a handful of occupations in the fabricated metal product manufacturing sub-sector are expected to be in high demand in the future, along with some skills and knowledge pieces for these respective occupations. One such occupation is mechanical engineering, which almost half of the survey respondents (46%) thought would be a future in-demand occupation. Respondents expected the most in-demand skills and knowledge in the future to be critical thinking skills, alongside production and processing, mathematical, and mechanical knowledge. More than a third of respondents (42%) also expected maintenance and plant supervisors to be in high demand in the future.[79] The skills expected by respondents to be in future high demand for supervisors are critical thinking, operations monitoring, and communications (reading, writing, active listening, and team monitoring) skills. Lastly, a small minority of respondents (21%) thought general machinists would be an occupation in high demand in the future. For general machinists, the skill and knowledge pieces respondents expected to be in high demand in the future are mechanical, mathematical, and processing and production knowledge, alongside skills in critical thinking and operations monitoring.

Computer and electronic product manufacturing

The industries represented in computer and electronic product manufacturing are Communications equipment manufacturing (NAICS 3342) and Semiconductor and other electronic component manufacturing (NAICS 3344). This sub-sector comprises establishments primarily engaged in manufacturing computers, computer peripheral equipment, communications equipment and similar electronic products, as well as components for all of these products.[80] Ontario is a hub for computer and electronic product manufacturing, accounting for nearly 55% of the value added from the sector nationally in 2019.[81] Business activities in the sector are disproportionately located in Toronto, while the Ottawa and Kitchener-Waterloo-Barrie economic regions also have strong clusters.

Key occupations in computer and electronic product manufacturing for auto and ZEV manufacturing are: user support technicians; supervisors of electronics manufacturing; supply chain, tracking and scheduling coordination occupations supervisors; electronics assemblers; and electronics inspectors.

Current workforce profile

Individuals involved in computer and electronic product manufacturing need and have strong skills in critical thinking, complex problem solving, and judgment and decision making. Quality control analysis is less important, but remains a top skill. Workers in this sub-sector are required to have strong expertise in the English language, computers and electronics, and customer and personal service. Design and mechanical knowledge are still important, but comparatively less so for workers in this sub-sector.

Table 9. Summary of top weighted-average skills and knowledge importance scores in computer and electronic product manufacturing

Skills	
Critical thinking	64.37
Complex problem solving	58.15
Judgment and decision making	56.19
Monitoring	55.74
Time management	53.75
Coordination	52.50
Social perceptiveness	51.28
Active learning	50.79
Operations monitoring	47.46
Quality control analysis	46.62

Knowledge	
English language	61.03
Computers and electronics	60.99
Customer and personal service	57.72
Mathematics	55.63
Administration and management	50.62
Engineering and technology	49.15
Production and processing	46.31
Education and training	43.34
Mechanical	42.45
Design	40.90

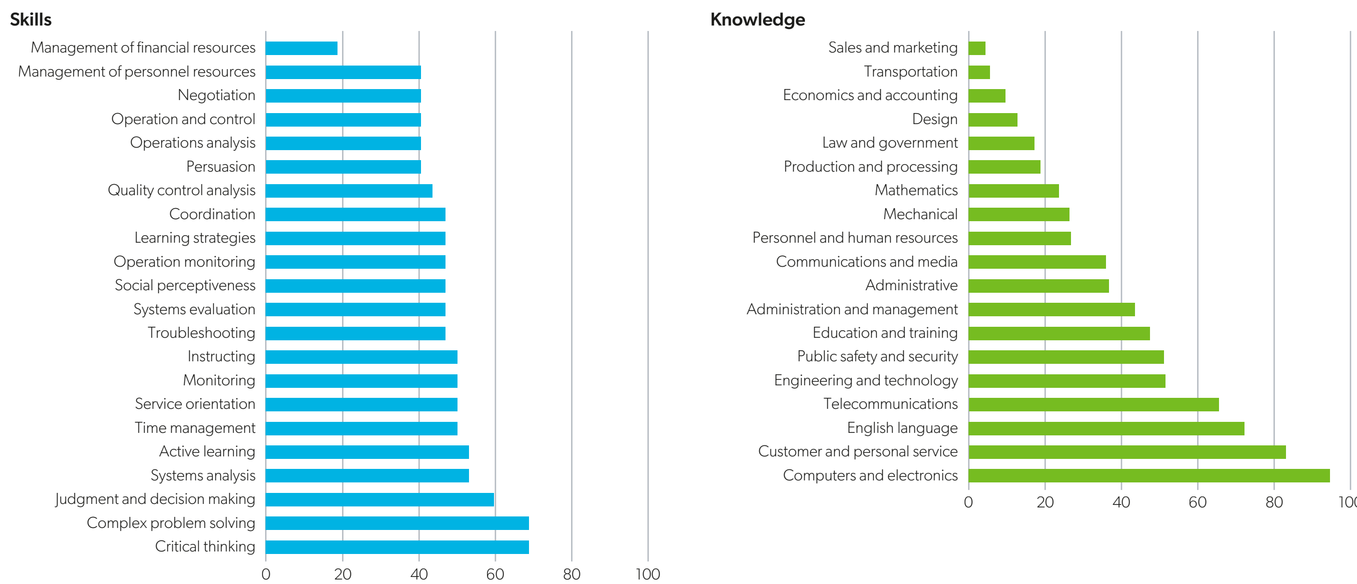
Table 9 shows the ten skills and knowledge areas that are most commonly found among the computer and electronic product manufacturing workforce, along with the weighted importance of skills and knowledge to computer and electronic product manufacturing workers on a scale of 1-100.

Electronics manufacturing supervisors and supply chain supervisors place noticeably high importance on management of personnel resources, time management, and social perceptiveness skills. Meanwhile, both electronics assemblers and electronics inspectors require operations monitoring skills. Required knowledge is more varied among the occupations. Supervisor roles require knowledge of production and processing, administration and management, customer support, and personnel and human resources. Supply chain supervisors however, require higher levels of knowledge in transportation and public safety, while electronics manufacturing supervisors require higher levels of computer and mathematical knowledge. Electronics assemblers and inspectors require engineering and technology knowledge, although electronic inspectors also require greater public safety, telecommunications, and customer service knowledge relative to assemblers. Aside from the very high importance of computers and electronics skills, user support technicians require business management and communication skills over engineering or mathematics knowledge.

Figure 7. Current skills and knowledge needed by workers in computer and electronic product manufacturing (absolute scores, 0–100)

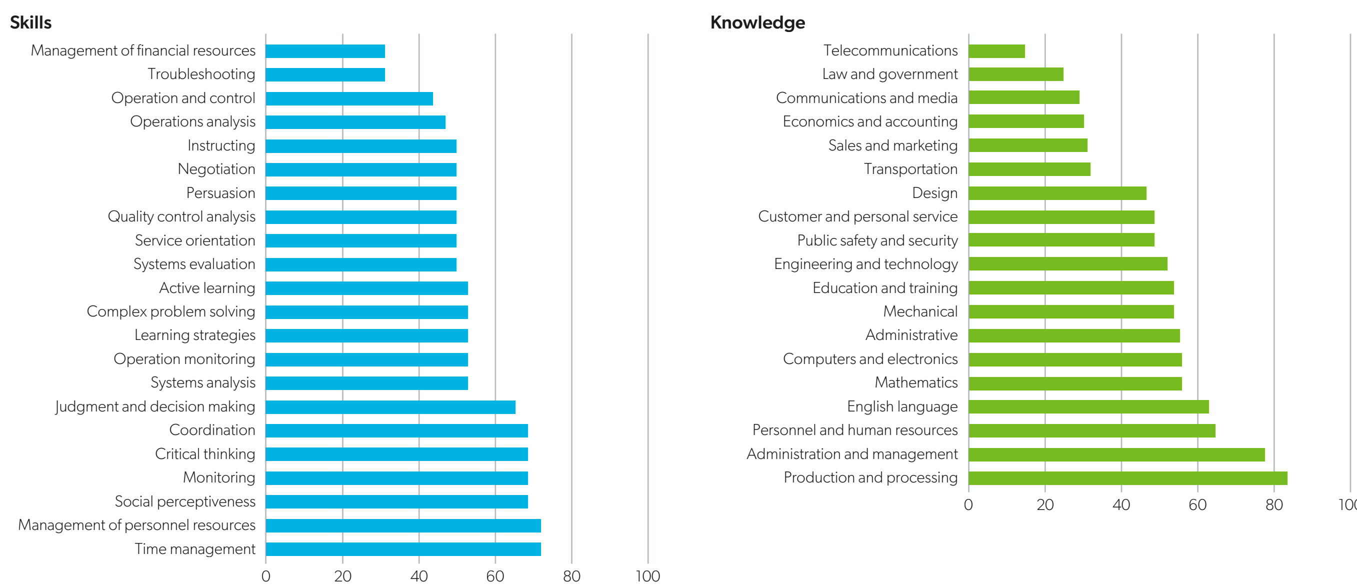
User support technicians

Figure 7-1



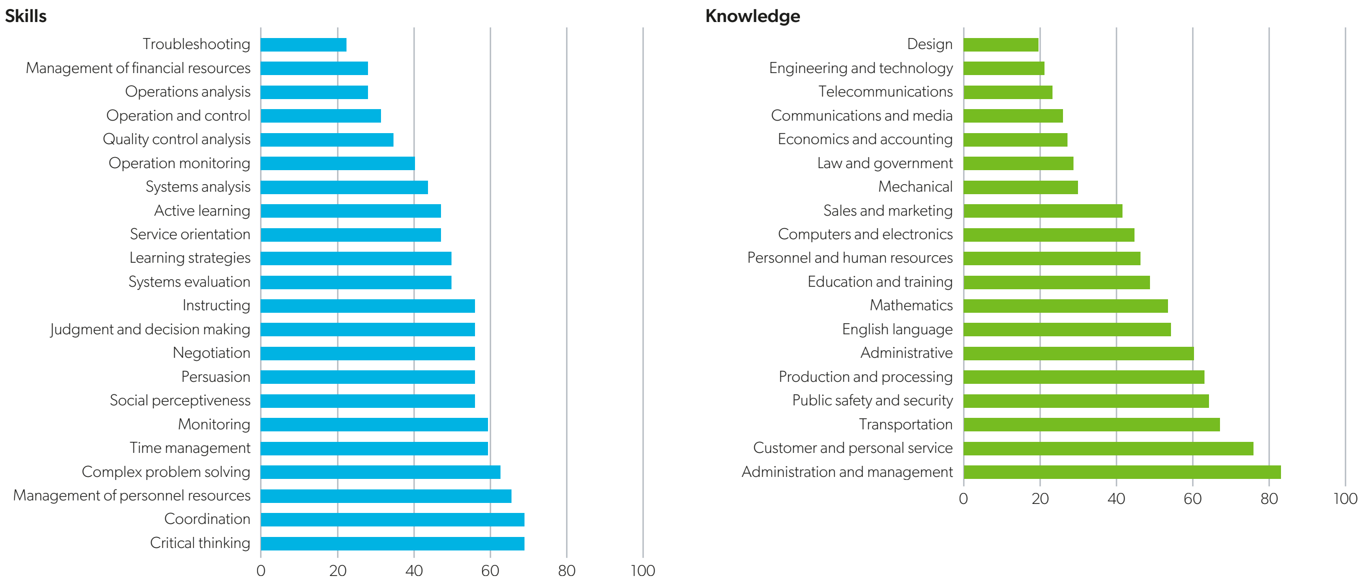
Supervisors, electronics manufacturing

Figure 7-2



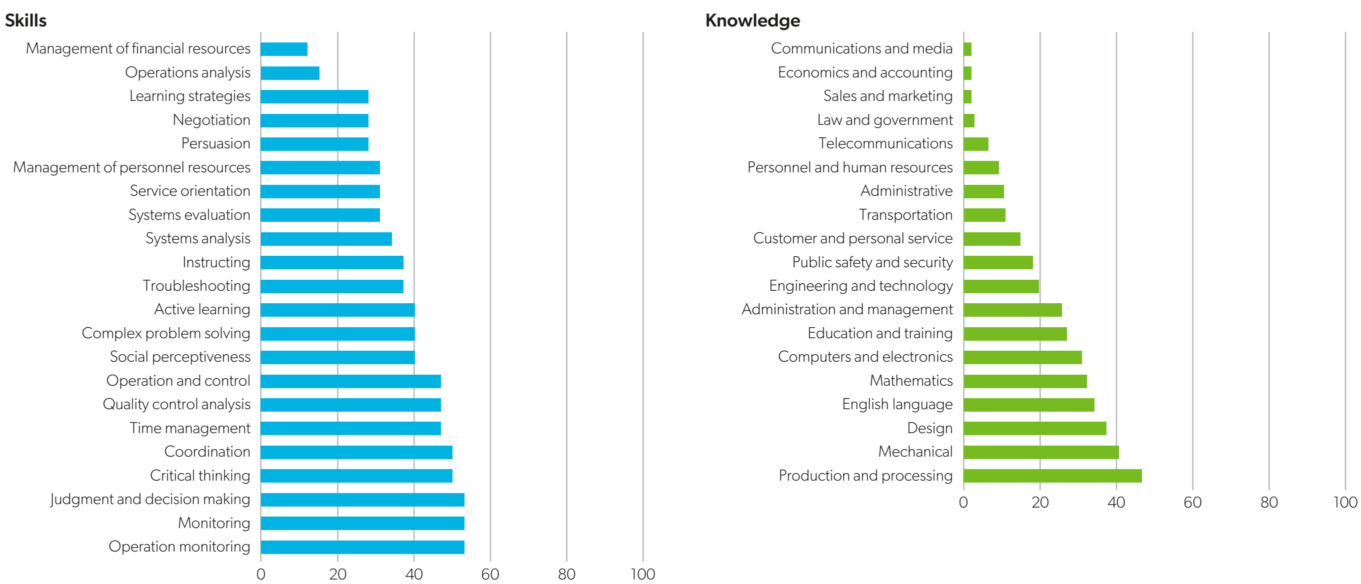
Supervisors, supply chain, tracking and scheduling co-ordination occupations

Figure 7-3



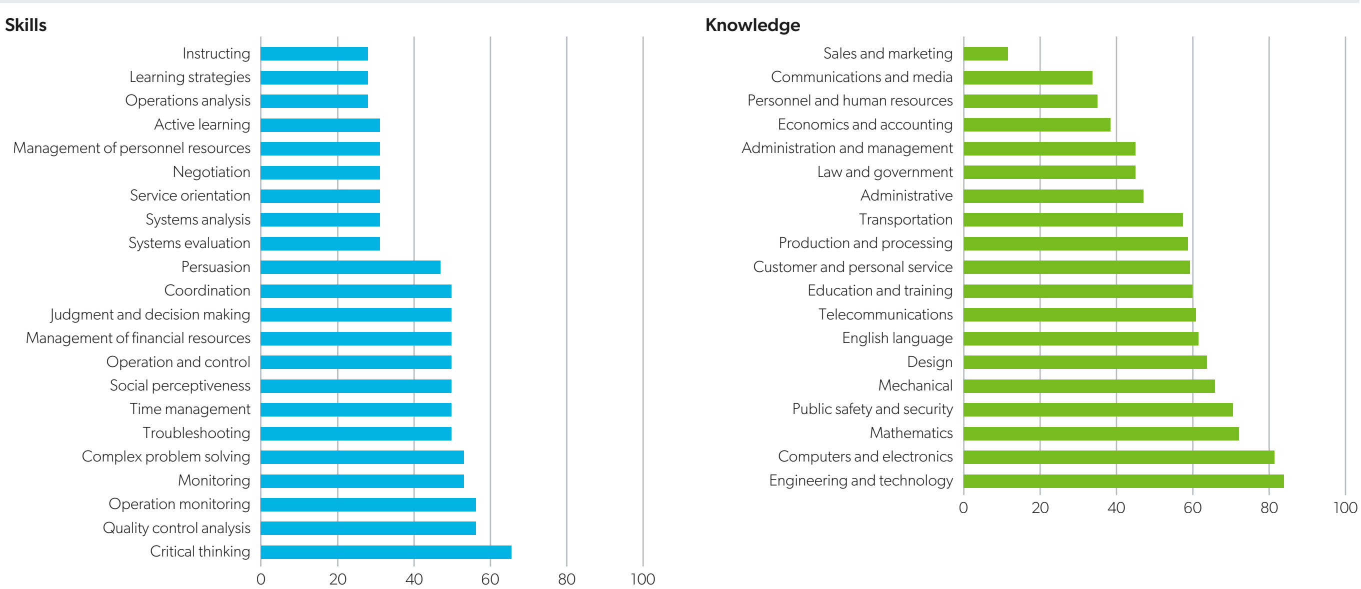
Electronics assemblers

Figure 7-4



Electronics inspectors

Figure 7-5



Future skills needs

This part of the sub-sector is involved in producing the Tier 2 sub-components of the ZEV supply chain by manufacturing communications equipment, semiconductor components, and other electronic components.[82] As vehicle powertrains move from ICEV to ZEV, semiconductor content per car (measured by value) will double.[83] In the ZEV powertrain, the charger, inverter, converter, high-voltage battery, central processor, and motor all require semiconductors.[84] Semiconductors are also produced in different sizes for different purposes. An additional challenge is the rate of innovation within drivetrains. Electric drivetrains change substantially in each vehicle generation, with the basic design of the drivetrain itself still evolving. The innovation cycle for electronic components in ZEVs is much faster than in internal combustion engines, meaning changes are not just incremental improvements, but leapfrogging previous generations.[85] To keep up with this shift, workers in the computer and electronic product manufacturing workforce will require strong complex problem solving and troubleshooting skills, enabling them to keep up with the changing industry, as well as strong systems knowledge, design skills, and programming languages skills.

Our foresight analysis from our survey of industry stakeholders identified a number of skills and knowledge pieces that would be the most in demand for occupations in the computer and electronic manufacturing sub-sector. Materials (including electronics) assemblers were identified by half (50%) of respondents as one of the jobs expected to be the most in demand by 2030. The skills and knowledge pieces expected to be the most in demand for this job are critical thinking skills, alongside production and processing, computer and electronics, and mathematical knowledge. Another occupation in this sub-sector, which more than a third of respondents (42%) expected to be in high demand in the future, is maintenance and plant supervisors. The skills expected by respondents to be in future high demand for this occupation are critical thinking, operations monitoring, and communications (reading, writing, active listening, and team monitoring).

Electrical equipment, appliance and component manufacturing

In this report, the industry represented in electrical equipment, appliance and component manufacturing is Other electrical equipment and component manufacturing (NAICS 3359). This sub-sector comprises establishments primarily engaged in manufacturing products that generate, distribute, and use electrical power.[86] This specific industry group however, is primarily engaged in manufacturing electrical power storage and transmission devices such as batteries and wiring devices.[87] Ontario has the largest number of employers in this industry, accounting for 47% of the national establishments,[88] with the majority in the Toronto and Peel regions.[89]

Key occupations in electrical equipment, appliance, and component manufacturing for auto and ZEV manufacturing are electrical products manufacturing supervisors; shippers and receivers; other labourers in processing, manufacturing, and utilities; other metal products machine operators; and electrical apparatus manufacturing machine operators.

Table 10. Summary of top weighted-average skills and knowledge importance scores in electrical equipment, appliance and component manufacturing

Skills	
Critical thinking	59.86
Monitoring	55.76
Judgment and decision making	53.79
Social perceptiveness	53.71
Coordination	52.58
Complex problem solving	51.82
Time management	51.72
Active learning	46.10
Persuasion	44.42
Service orientation	42.49

Knowledge	
English language	61.84
Mathematics	56.73
Customer and personal service	55.86
Production and processing	52.10
Computers and electronics	50.67
Administration and management	50.13
Mechanical	40.79
Administrative	39.63
Education and training	39.27
Public safety and security	35.63

Table 10 shows the ten skills and knowledge areas that are most commonly found among the electrical equipment, appliance and component manufacturing workforce, along with the weighted importance of these skills and knowledge areas to electrical equipment, appliance and component manufacturing workers on a scale of 1-100.

Current workforce profile

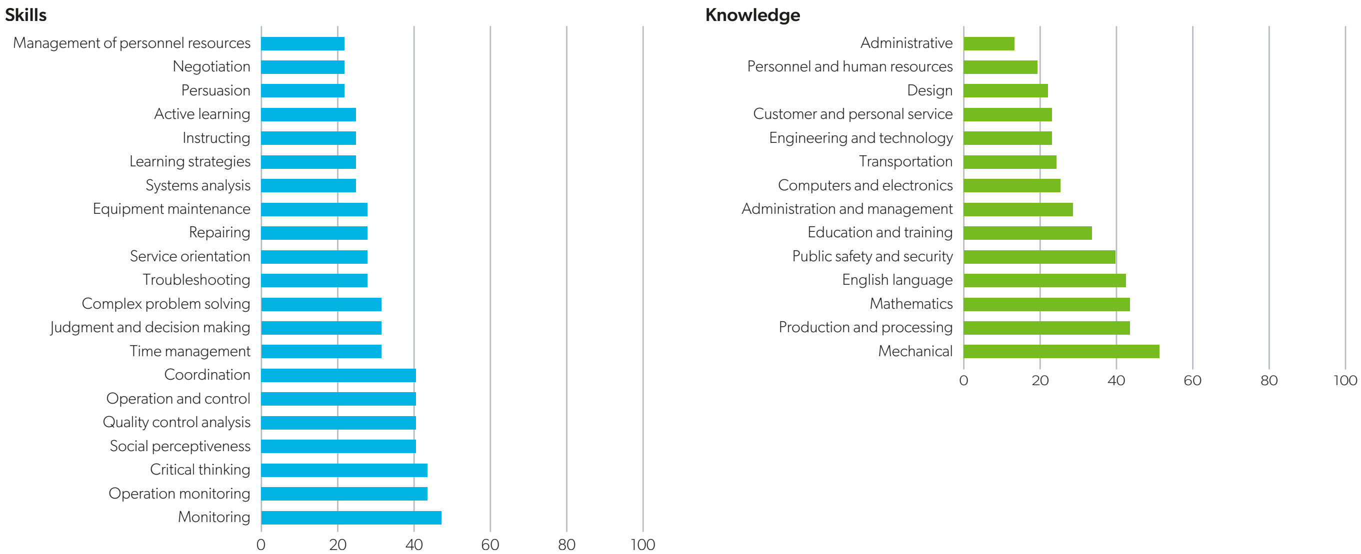
Individuals involved in electrical equipment, appliance, and component manufacturing need strong skills in critical thinking, monitoring, and judgment and decision making. Service orientation is less important, but remains a top skill. Workers in this sub-sector are required to have strong expertise in English language, mathematics, and customer and personal service. Knowledge in public safety and security, as well as knowledge in education and training, are also important, but comparatively less so for workers in this sub-sector.

Within operator occupations, technical skills like quality control, troubleshooting, and equipment maintenance and repairing are more important for other metal products machine operators than for electrical apparatus manufacturing machine operators. On the other hand, electrical apparatus manufacturing machine operators require more judgment and decision making skills. The importance of operations monitoring is highest for other metal products machine operators, while resource management skills is highest for electrical products manufacturing supervisors. Production and processing knowledge is of high importance for each occupation; it is most important for electrical products manufacturing supervisors and other metal products machine operators. Labourers and metal products machine operators require high levels of mathematics, English language, and mechanical knowledge. For supervisors and shippers, administrative and management knowledge and knowledge of computers and electronics are of high importance. Except for electrical apparatus manufacturing machine operators, education and training knowledge is of relatively high levels of importance to the selected occupations.

Figure 8. Current skills and knowledge needed by workers in electrical equipment, appliance and component product manufacturing (absolute scores, 0–100)

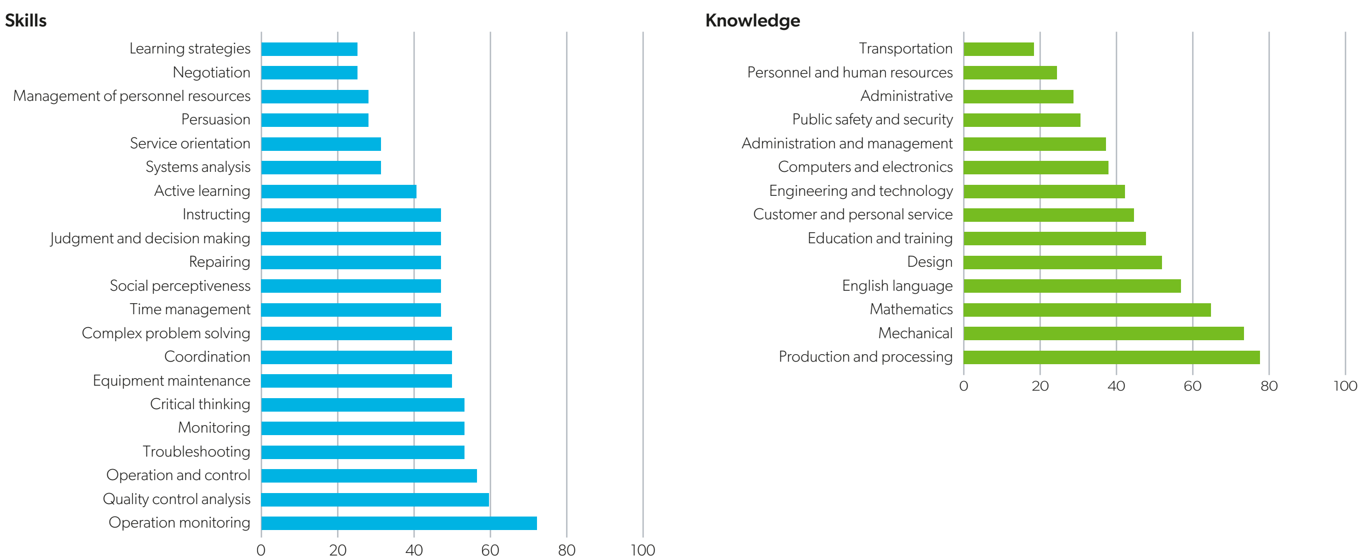
Other labourers in processing, manufacturing and utilities

Figure 8-3



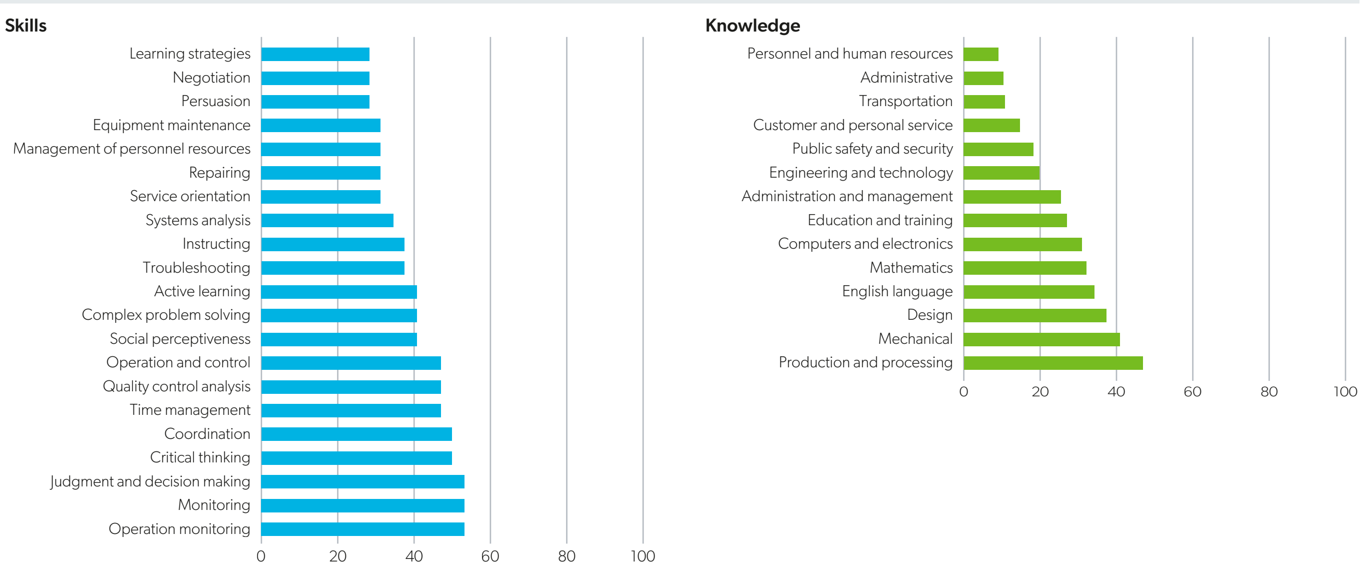
Other metal products machine operators

Figure 8-4



Machine operators, electrical apparatus manufacturing

Figure 8-5



Future skills needs

This part of the sub-sector is involved in producing the Tier 2 sub-components of the ZEV supply chain by manufacturing electrical equipment and components. The key industry in this sub-sector is battery manufacturing.[90] The presence of battery packs is a key difference between ZEVs and ICEVs. The lithium-ion batteries that ZEVs typically use are manufactured in battery production plants through the stages of electrode manufacturing, cell assembly, and cell finishing. After the battery cells are assembled through separation, stacking, winding, packaging, and electrolyte filling, cell finishing includes testing, which ranges from pulse tests to leakage tests. Simulations and tests are performed on battery designs to validate them. Research and development also enter the picture in a constant effort to improve the energy density, life span, and stability of batteries.[91]

As demand for ZEVs and their batteries increases, more ZEV battery plants will be required, impacting the number and composition of this sub-sector's workforce. Chemical engineers, chemists, and material scientists have been identified as key occupations necessary for the battery manufacturing stage of the ZEV value chain.[92] Electrical and mechanical engineers are needed to design and develop battery components, as well as undertake research for new technologies. Skills in maintaining automation systems, alongside electrical and mechanical skills specifically related to ZEVs and battery energy storage systems, will be of increased importance.[93]

From our survey of industry stakeholders, a handful of skills and knowledge pieces are expected to be in future high demand for occupations in the electrical equipment, appliance and component manufacturing sub-sector. Almost three-quarters (71%) of survey respondents thought electrical engineers would be one of the most in demand future jobs in the sector. For this occupation, expected future high-demand skills and knowledge pieces are critical thinking and communications (reading, writing, and active listening) skills, alongside production and processing, computer and electronics, mathematical, and mechanical knowledge. For mechanical engineering, which almost half of the survey respondents (46%) thought would be an in-demand occupation in the future, the skills respondents expected to be most in demand in the future are similar to those of electrical engineers. These are critical thinking skills, alongside production and processing, mathematical, and mechanical knowledge. Another occupation in this sub-sector, which more than a third of respondents (42%) expected to be in high demand in the future, is maintenance and plant supervisors. The skills expected by respondents to be in future high demand for this occupation are critical thinking, operations monitoring, and communications (reading, writing, active listening, and team monitoring). Lastly, a small minority of respondents (21%) thought general machinists would be an occupation in high demand in the future. For this occupation, the skills and knowledge pieces respondents expected to be in high demand in the future are mechanical, mathematical, and processing and production knowledge, alongside critical thinking and operations monitoring skills.

Transportation equipment manufacturing

In this report, the industries represented in transportation equipment manufacturing are Motor vehicle manufacturing (NAICS 3361) and Motor vehicle parts manufacturing (NAICS 3363). This sub-sector comprises establishments primarily engaged in manufacturing equipment for transporting people and goods, specifically for road transportation.[94] Ontario is the centre of motor vehicle, body, trailer and parts (MVBTP) manufacturing in Canada, having nearly 80% of Canadian employment in the sector and employing 136,300 people in 2021.[95] The industry is anchored by major motor vehicle assembly plants in the Kitchener-Waterloo-Barrie, Toronto, London, and Windsor-Sarnia economic regions.[96] 78% of Ontario's MVBTP manufacturing workforce in 2021 were male, compared to around half in all industries, while workers aged 55 years and overrepresented almost a quarter of Ontario's MVBTP workforce.[97]

Key occupations in transportation equipment manufacturing for auto and ZEV manufacturing are other metal products machine operators, motor vehicle assemblers, motor vehicle inspectors and testers, motor vehicle assembling supervisors, and metalworking machine operators.

Current workforce profile

Individuals involved in transportation equipment manufacturing need strong skills in critical thinking, monitoring, and operations monitoring. Operation and control is less important, but remains a top skill. Workers in this sub-sector are required to have strong mechanical expertise, knowledge in mathematics, and high English language competency. Knowledge in public safety and security, and engineering and technology, are also important, but comparatively less so for workers in this sub-sector.

Other metal machine operators, motor vehicle assemblers and inspectors, and metalworking machine operators all require a skill set where technical skills, such as operations and quality control analysis, and basic process skills, like critical thinking and monitoring, are most important. On the other hand, motor vehicle assembling supervisors require a skill set where non-technical skills hold far more importance, including coordination, managing time and people, and judgment and decision making. Metalworking and metal product machine operators require a similar knowledge profile consisting of production and processing, mechanical, mathematics, and design. Motor vehicle assemblers require knowledge of transportation, the English language, and public safety, while customer service and sales knowledge is more important for motor vehicle inspectors. On the other hand, supervisors of motor vehicle assembling require administrative and management knowledge.

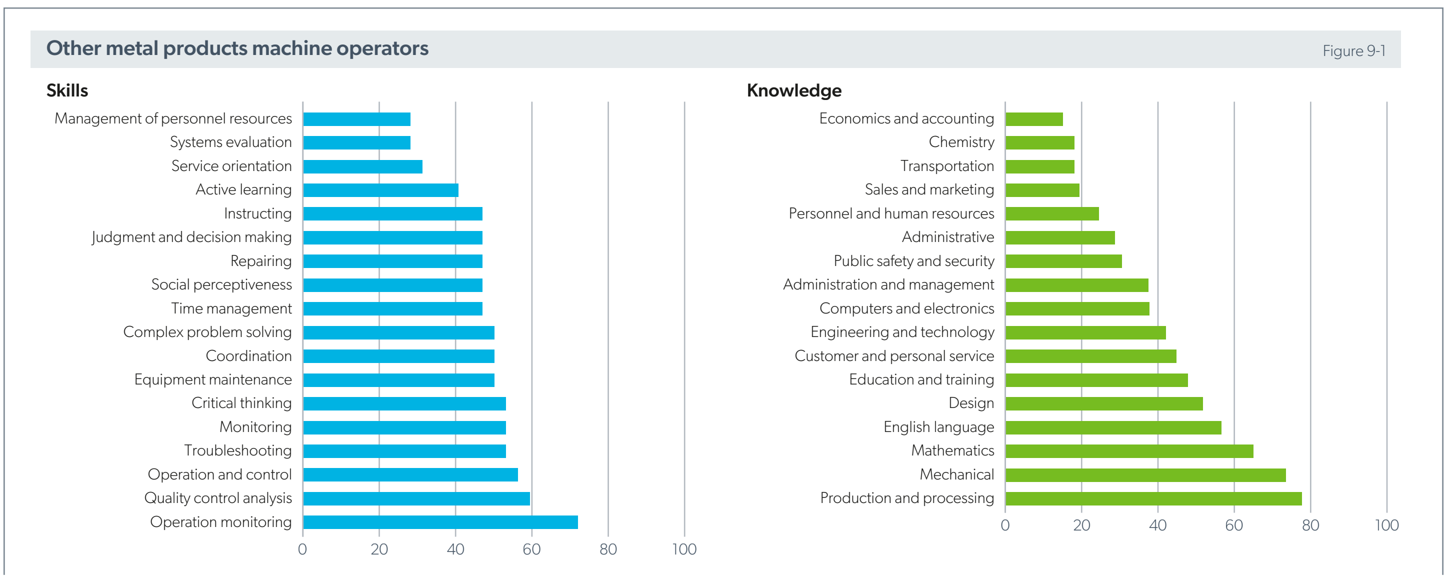
Table 11. Summary of top weighted-average skills and knowledge importance scores in transportation equipment and manufacturing

Skills	
Critical thinking	57.75
Monitoring	55.39
Operations monitoring	55.29
Time management	51.67
Judgment and decision making	51.46
Complex problem solving	50.55
Coordination	50.49
Quality control analysis	50.17
Social perceptiveness	47.38
Operation and control	46.77

Knowledge	
Mechanical	58.89
Mathematics	57.10
English language	57.01
Production and processing	54.84
Customer and personal service	53.16
Administration and management	48.74
Education and training	44.45
Computers and electronics	43.98
Engineering and technology	41.32
Public safety and security	39.82

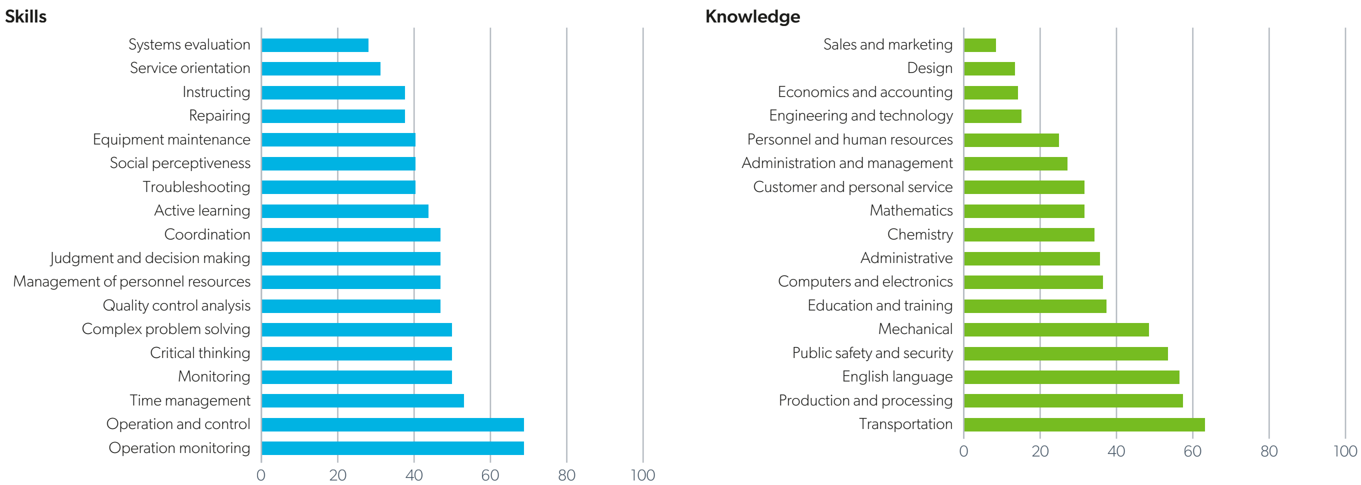
Table 11 shows the ten skills and knowledge areas that are most commonly found among the transportation equipment manufacturing workforce, along with the weighted importance of these skills and knowledge areas to transportation equipment manufacturing workers on a scale of 1-100.

Figure 9. Current skills and knowledge needed by workers in transportation equipment manufacturing (absolute scores, 0–100)



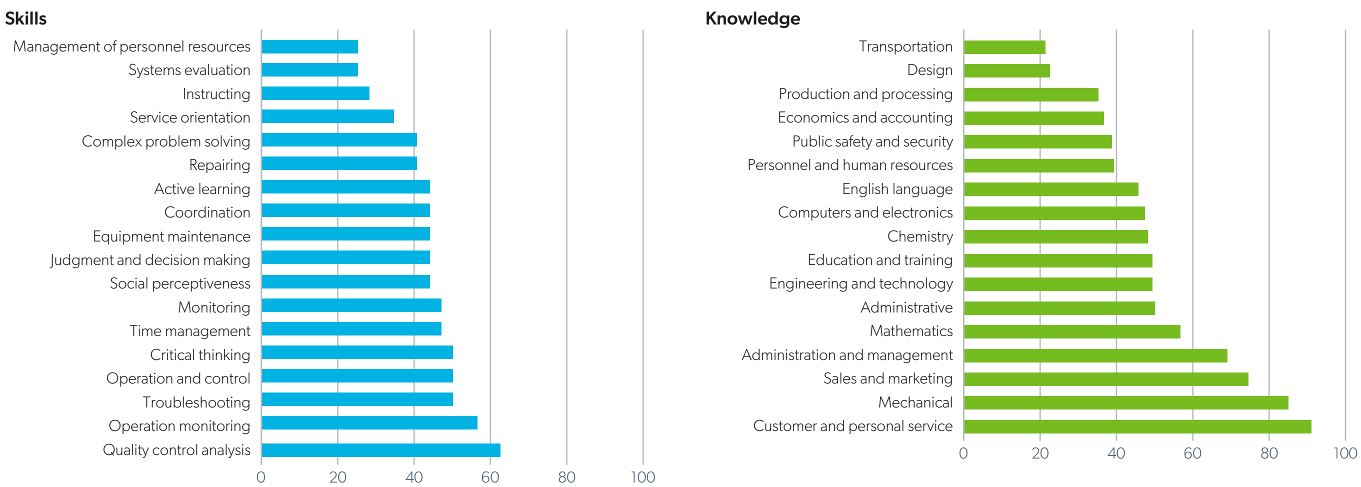
Motor vehicle assemblers

Figure 9-2



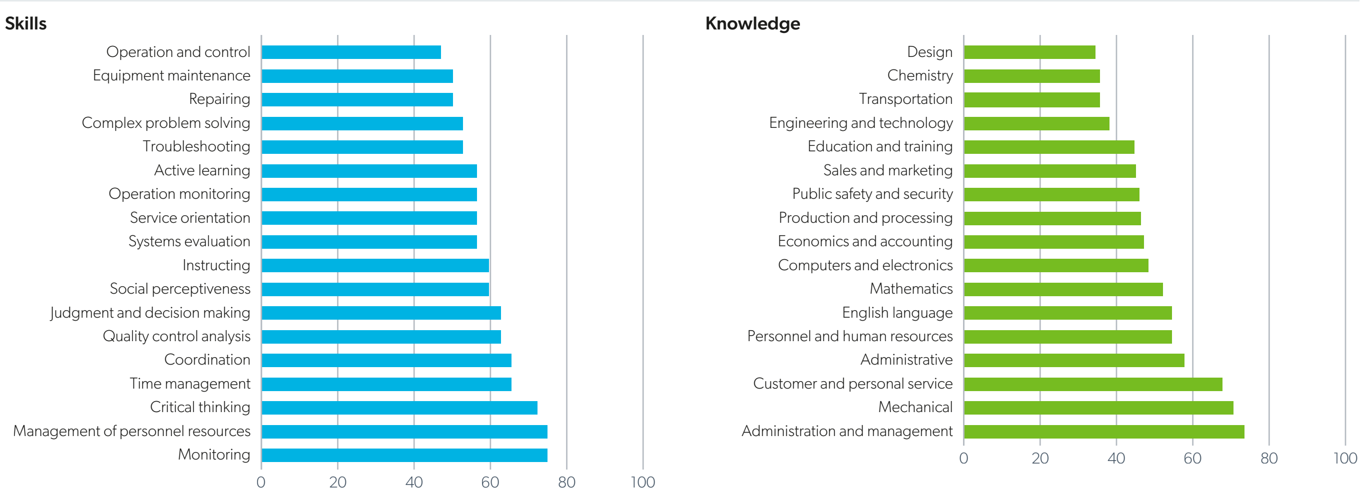
Motor vehicle inspectors and testers

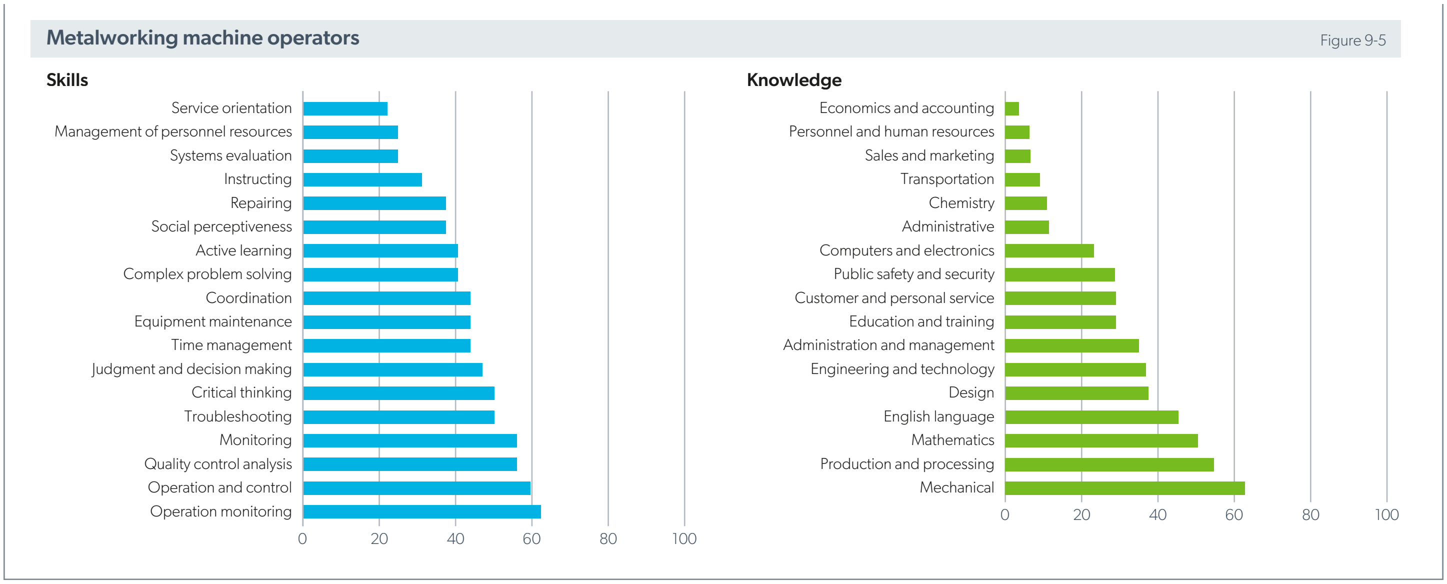
Figure 9-3



Supervisors, motor vehicle assembling

Figure 9-4





Future skills needs

This part of the sub-sector is involved in producing the Tier 1 sub-components of the ZEV supply chain and OEM vehicle assembly by manufacturing motor vehicles and motor vehicle parts, including engines.[98] The most significant impacts in the shift from ICEVs to ZEVs will be felt by the absence of certain motor vehicle parts, such as internal combustion engines. For the manufacturing of motor vehicles, there will also be minor assembly changes. For example, while both ICEVs and ZEVs involve hydraulic cylinders and approximately the same number of robotics for assembling vehicles, the assembly process could differ depending on the materials used for the body panels. Even within ZEVs, there are multiple ways to install components, like battery packs, which differ by when the battery is introduced to the process and the attaching of different structural components.[99] The final assembly is also expected to have different processes, automation, and controls due to the power electronic components that aid battery packs.

According to industry stakeholders, there will not be a significant difference for assembly workers in the shift to ZEVs. While there are differences in the machinery and equipment used and assembly processes for ZEVs, existing assembly knowledge for ICEVs is highly transferable for ZEV assembly. Plant workers with powertrain assembly and final assembly experience could be retrained on electric component assembly and new quality assurance requirements.[100] Some new roles will be necessary to complete ZEV assembly, such as software engineers to install the ZEV hardware and software systems needed to function. Battery management system engineers also will be crucial to monitor and regulate the battery pack.[101] Additionally, new hybrid roles could be required. For example, there may be a need for a role that sits between a millwright and a general operator and has both basic line knowledge and an understanding of programmable logic controllers.[102] ZEVs also will require fewer components, which could have an impact on the number of workers required.

From our survey of industry stakeholders, a handful of occupations in the transportation equipment manufacturing sub-sector are expected to be in high demand in the future, along with some skills and knowledge pieces for these respective occupations. One such occupation is battery process and management engineer, which almost three-quarters (71%) of respondents selected as a future high-demand occupation. The skills and knowledge pieces expected to be in high demand for battery process engineers are mechanical knowledge, knowledge in production and processing, and critical thinking and communications (such as reading, writing, and active listening) skills. Another occupation that more than half of respondents (58%) expected to be in future high demand is software developers who will work with software engineers to install and design the software systems ZEVs will need to function. The skills and knowledge pieces respondents expect to be in future high demand for software developers are critical thinking and communications (reading, writing, and active listening) skills, alongside computer and electronics knowledge.

More than a third of respondents (42%) also expected plant supervisors to be in high demand in the future.[103] The skills expected by respondents to be in future high demand for this occupation are critical thinking, operations monitoring, and communications (reading, writing, active listening, and team monitoring). Lastly, a small minority of respondents (21%) thought general machinists would be an occupation in high demand in the future. For this occupation, the skills and knowledge pieces respondents expected to be in high demand in the future are mechanical, mathematical, and processing and production knowledge, alongside critical thinking and operations monitoring skills.

Outlook for workers manufacturing ZEVs

The shift from producing ICEVs to ZEVs and the subsequent changes to supply chains will have impacts on Ontario's manufacturing sectors. While this report has so far identified the changes for each sub-sector of the supply chain, trends such as automation and skilled labour shortages will impact workers throughout the supply chain. Additionally, regions across Ontario will need to manage the growth that new investments are expected to bring about. The following section details the overall outlook for workers and communities across the province, highlighting important themes and specific challenges.

In addition to the survey, PLACE also held workshops in London and Windsor, ON, in March 2023. Organised in collaboration with Workforce Windsor Essex (WWE), the London Economic Development Council (LEDC), and the London Region Manufacturing Council (LRMC), the workshops had 64 attendees in total, comprising automotive sector employers, training institutions, provincial ministries, and employment service providers (ESPs) in both regions. These attendees participated in discussion groups which provided PLACE with key and contextualised information on the automotive sector in the region, which will be referenced in this discussion section.

Which occupations and skills will be most in demand throughout the entire supply chain?

Electrical engineers and battery process engineers are anticipated to be the most in-demand occupations in the automotive and electric battery manufacturing sector between now and 2030. Over two-thirds of survey respondents (71%) believed this to be the case, followed by a little more than half (58%) anticipating software developers to also be highly in demand. Other occupations anticipated to be in high demand in the future are industrial electricians and materials assemblers (both 50%). All top 5 in-demand occupations were expected to need strong critical thinking skills and production and processing knowledge. While mechanical knowledge was expected to be less important for software developers than the other occupations, communications skills and computer and electronics knowledge were deemed of higher importance. In addition to software developers, electrical engineers and material assemblers will also possess computer and electronics knowledge, reflective of the greater requirements of circuit boards, processors, chips, electronic equipment, and programming in ZEV manufacturing. More generally, across the sector, critical thinking (54%), production and processing knowledge (54%) and communications skills (45%) were expected by respondents to be the skills and knowledge of the highest importance but also at the highest risk of future shortages.

Which trends will impact workers across the supply chain?

One trend that will have the most significant impact on workers across the auto manufacturing sub-sector is the adoption of automation solutions, robotics, and digital technologies. Importantly, digital skills are often not entirely distinct from other skills. Rather, the use of a digital solution frequently takes what was an analog process and allows it to be completed using specialized software or robotics. For example, project management now requires access to and familiarity with specific software tools as well as important knowledge pieces, such as being familiar with manufacturing practices. As referenced earlier in this report, solutions—such as robotic machines in assembly and production, the use of big data and analytics, and more digital and computer programming for manufacturing design, production, and maintenance—are increasingly standard within the manufacturing sector. These changes will require specialised skills and knowledge, such as electrical and chemical engineers needing coding or battery management expertise, machinists possessing greater programming and software knowledge, and electrical engineers having coding and software design expertise.[104] Additionally, certain occupations and sectors will see strong increases in demand, including roles within the Electrical equipment and component sub-sector (NAICS 3359) with expertise in battery technologies. These roles include controls technicians, electrical and electronics engineers, electricians, industrial engineers and manufacturing technologists and technicians, mechanical engineering technologists and technicians, metallurgical and materials engineers, and software developers, to name a few.[105] Chemical engineers, chemists, and material scientists have also been identified as key occupations necessary for the battery manufacturing stage of the ZEV supply chain. Beyond adapting technology for production, it will be used more for logistics, coordination, and communication, such as supporting enterprise resource planning.[106] Some of this increased technology and automation use will lead to worker transitions. Workers in the motor vehicle manufacturing sub-sector working on the chassis and powertrain systems will experience some of the greatest change. The skills, knowledge, and education required for work on an ICEV are not directly transferable across all occupations, meaning retraining or upskilling will be required for those workers in order to continue to work on ZEV automotive systems. For example, without retraining, jobs in the ZEV battery cell manufacturing may not be filled by those that currently produce engines or other ICE engine-related parts. However, our research has shown that this is not the case across all sectors. Vehicle assembly skill sets are highly transferable, meaning little additional training or education will be required to support ZEV assembly, aside from additional health and safety knowledge around managing electricity and batteries.[107]

Another trend impacting the sector is an aging manufacturing workforce. In the manufacturing sector as a whole, the proportion of employees aged 55 and over has tripled from 8% in 2000 to just under 24% in 2018.[108] For Ontario's automotive and automotive parts manufacturing sector, stakeholders voiced the pressing nature of this challenge, with participants in the Greater London Area detailing that roughly 60% of the manufacturing workforce was within five years of retirement. Previous research from FOCAL has identified a projected recruitment gap (a gap between the size of the current labour force and that which is required for the future) of 30,000 employees for Ontario's automotive sector, which represents nearly 20% of the core automotive manufacturing workforce in 2020.[109] Almost two-thirds of surveyed respondents (62.5%) thought the sub-sector's aging/retiring workforce would be a driver of future skills and labour shortages. They also cited the challenge of retiring workers taking valuable knowledge, skills, and experience with them that could now not be passed onto younger employees. This anxiety reflects a key challenge that occurs when retirements figures exceed the number of newcomers entering an industry: employers, and by extension the sector, see a reduction in experienced skilled workers, and apprentices have fewer experienced workers to teach and supervise them, thereby creating challenges for both workers and firms. Improving the ratio of skilled workers to apprentices will be critical, but given the supervision requirements for apprentices, it may also place additional pressure on firms.

What is holding back stakeholders from addressing these challenges?

Stakeholder feedback showed that one of the biggest current limitations holding back workforce planning to deal with some of these impacts of the ZEV transition is the lack of transparency from OEMs and new facilities regarding their job descriptions and skills needs. This uncertainty makes it especially difficult for local stakeholders, such as training colleges, unions, and ESPs, to know how best to train and prepare workers for the incoming change. With these ZEV and battery plants slated to begin production within the next year and a half, these stakeholders fear that they will not have enough time to both adequately train new entrants into the sector and retrain current or transitioning workers. Although Stellantis-LG is working closely with St. Clair College in Windsor, ON to develop programs and training to staff the plant,[110] this is only one arrangement for one college in one area and may not be as replicable in bigger or more populous regions with more post-secondary institutions (PSIs). Such an arrangement also leaves out ESPs and labour unions, who also have a part to play in training. Furthermore, while some OEMs have mentioned that they will have "preferential hiring" for union members, stakeholder feedback showed that it only applies to priority for interviews, not guaranteed jobs for transitioning workers. This is not independently a challenge, but unions emphasized that the lack of transparency about skills needs made it difficult to support their members as they prepared for interviews. Without an understanding of skills and knowledge needs, it was unclear if workers should invest in training or upskilling, or which components of their skill sets should be emphasized. This lack of clarity is a major challenge for job seekers.

Another issue affecting workforce planning is a lack of sufficient training or upskilling opportunities for new or transitioning workers working in the ZEV supply chain. Two-thirds (66.7%) of surveyed respondents identified a "lack of appropriate education/training options" for students/recent graduates as a main reason for various expected future skills shortages, while more than half (58.3%) identified "a lack of reskilling/retraining options for current workers" as another challenge. For new graduates/incoming workers, the root of the issue was identified as beginning at the secondary school level. Amongst the problems respondents highlighted were a decreased emphasis on the skilled trades, underfunded shop or co-op programs, the historic effects of academic streaming in Ontario, ineffective marketing of manufacturing and skilled trades careers by parents and counsellors to secondary students (which was partly due to changes in perspectives about the stability of employment in the automotive sector following the 2008-2009 recession), and academic counsellors' lack of awareness of the sector.[111] 45% of survey respondents identified "insufficient sector interest to attract new workers" as a reason for expected future skills shortages.

An identified challenge further along in the workforce training pipeline for recent graduates/incoming workers is a "lack of pathways" between apprenticeship training delivery agents, like unions and employers, and PSIs. This refers to the ease of transferring to enrol in a PSI for young apprentices whose training delivery agent was a union/employer, should an apprentice or tradesperson wish to pursue further education. The process for getting academic credits or qualifications after doing an apprenticeship with a training delivery agent has been cited as difficult and disincentivizing for apprentices looking to make the switch, employers and unions who provide the training or are looking to hire, and PSIs who would like to play their part in training the workforce. Stakeholders cited this challenge as being mostly administrative, as apprenticeship and skilled trades training responsibilities are managed by both the Ministry of Colleges and Universities and the Ministry of Labour, Immigration and Skilled Trades. Given that many skilled tradespeople will require additional certifications or training to upskill and learn new skills as opportunities emerge, this difficulty could serve as a barrier to upskilling. This is an issue for the sector because the sector loses out on potentially well-rounded professionals who have the technical and hands-on experience of an apprenticeship and the academic qualifications and know-how of an engineer, for example. It may also reduce the reliance on microcredits further into apprentices' or journeypersons' careers, as they may feel they have a lower opportunity cost (i.e., less earnings to lose out on) earlier in their careers versus later on, when they are more established and/or earning for their families.

At the midpoint of the workforce training pipeline, employers also have voiced concerns about training and education. These concerns are about the cost (time and financial) of reskilling or upskilling employees, along with the risk of poaching from competitors after training. Discussions with stakeholders found this to be a common practice, with some employers citing that poaching skilled trades workers was occurring both within and between different industries.[112] Given these concerns, employers would rather hire ready-made workers than expend the resources to train workers who may then go to a competitor. Additionally, even if the employer is willing and able to provide this training to current workers, the employer stands to lose out on the employees' contributions on the shop or plant floor since working and training at the same time are almost impossible. More than half of survey respondents (59%) identified financial cost as the biggest barrier to upskilling and reskilling workers, while half (50%) identified the time it takes to organise and deliver the training as another major barrier to upskilling and retraining.

Another workforce planning obstacle is the wages in the manufacturing sector. In 2022, Ontario's manufacturing sector had a lower average hourly pay ($30.83) than the overall (across all industries) hourly average wage ($32.94) for all workers (aged 15 and above).[113] This also was the case for prime-age (25 to 54-year-old) workers in 2022, with the sector's prime-age workers making an average of $31.99/hour, compared to the provincial average of $35.59/hour. This discrepancy in earnings goes back to 2004 for prime-age workers.[114] While these are the numbers for the manufacturing sector as a whole and not just automotive manufacturing or the sub-sectors we focus on in this report, it is still a challenge for the automotive sector that was brought up in stakeholder discussions and has been addressed in previous automotive sector reports.[115] A 2019 APRC wage report found that some production and skilled trades occupations wages across NAICS 3361 (Motor vehicle manufacturing) and NAICS 3363 (Motor vehicle parts manufacturing) were "…not keeping pace with wages in other sectors such as construction or utilities" and that wages were lower in parts production than in assembly.[116] Paying lower than average wages makes it challenging for the sector to attract or retain new and/or younger workers, especially for those in the larger and denser urban areas, such as the Greater Toronto Area, where workers have more employment opportunities and the cost of living is higher. The reality of lower-than-average earnings also impacts older workers or workers near retirement, whom stakeholders have identified as often retiring early and collecting their pensions or taking up similar paying but less physically taxing jobs in other sectors like retail, which are seen as more attractive alternatives than continuing to work in the automotive sector.

Where will impacts be geographically concentrated and what will it mean for communities?

Geographically, the bulk of the skills and labour impacts of the shift from ICEVs to ZEVs can be expected to be concentrated in South-Western Ontario, particularly the Windsor-Essex and Greater London Area regions. These two regions have high concentrations of automotive manufacturing and have also seen the biggest ZEV and battery investments.[117] Other areas and sectors that will be affected include the Hamilton-Niagara peninsula (non-metallic mineral product manufacturing[118]), Kitchener-Waterloo-Barrie (non-metallic mineral product, plastics and rubber, fabricated metal product, transportation equipment,[119] and some electronic product manufacturing), and Greater Toronto Area (non-metallic mineral product, fabricated metals,[120] plastics and rubber manufacturing,[121] computer and electronic product and electrical equipment, appliance and component manufacturing[122]) regions.

Investment and skills changes in these regions will have a number of impacts on communities themselves that provincial and municipal governments will need to address. Based on a combination of our stakeholder survey, workshops, and other data, the biggest impacts on the regions mentioned above will arise from two challenges: their need to attract more workers to plug labour shortages and building out the infrastructure required to support new investments. These changes will be most visible for regional infrastructure, specifically for transit and transportation infrastructure, housing, and training infrastructure. There is a need to build additional housing in regions keen to attract more workers to plug labour shortages.[123] In areas of major investment, such as London-St Thomas, announcements of new automotive and battery manufacturing plants are prompting fears of price increases in an already costly housing market in need of more supply.[124] Given that much of Canada's new skilled labour comes from immigration, most of whom, depending on the city they move to, do not always have the money to pay high prices for rental housing,[125] accommodating new workers is something that policymakers will have to address.

Public transit is another example of infrastructure that will be impacted by the ZEV transition. For regions' existing transit systems, the influx of new workers may put further strain on existing transit systems and routes. For some communities where investment is being directed into regions that have not historically been hubs for public transit (like in the Greater London Area and Windsor-Essex), policymakers and, where possible, employers will have to consider ways to ensure their employees can get to work in a timely and convenient fashion. Finally, ESPs will be impacted by this transition. This includes a range of organizations and stakeholders such as Service Ontario, Better Jobs Ontario, and YMCA Action Centres created by Unifor to support recently laid-off workers. ESPs are likely to see an increase in the use of their services as workers subject to layoffs seek to retrain and others seek opportunities to upskill. For ESPs who will see demand for services increase, additional funding, coordination, and collaboration will be essential to ensure they are appropriately resourced and that individuals seeking supports are connected to the services they need. It will also be critical for governments and employers to ensure approaches to funding and engaging with ESPs do not make this task more difficult, such as by failing to engage with ESPs or offering funding that is not flexible enough to be customized to local labour market needs.

Recommendations

Coordinated action by policymakers, educational institutions, and employers is needed to support as smooth a transition as possible of workers to working on ZEV and battery manufacturing. This report reveals a few challenges and recommendations for developing policies and practices to respond to Ontario's shift to manufacture ZEVs and ensure workers are equipped with the necessary skills and knowledge to succeed.

Recommendation #1: Strengthen the mandates of the Canadian Automotive Partnership Council (CAPC) to address uncertainty about future skills training needs and tackle sectoral talent shortages.

A challenge for Ontario's automotive manufacturing sector in the transition to ZEVs is the lack of transparency and collaboration between OEMs about the future skills and knowledge needs. Currently, the extent to which stakeholders know what skills and training OEMs will need takes shape as one-off agreements between two parties. While useful for the involved stakeholders, this gatekeeping of skills and knowledge information excludes other employers and relevant stakeholders while preventing the training, retraining, or upskilling of the existing and future workforce. Thus, it is necessary to improve the availability and quality of labour market information regarding skills and knowledge requirements to inform opportunities to prepare the existing workforce. The best workforce development solutions happen when leading employers come together to address the talent problem for an entire sector, with competitors collaborating because they all face the same talent problem. One such example is the Advanced Manufacturing Technical Education Collaborative (AMTEC) in the United States which includes 19 automotive companies and 26 community colleges in 13 states who work together to strengthen the competency and global competitiveness of the advanced manufacturing workforce.[126] This is similar to a sector council, which is defined as "…a joint employer-employee organisation that provides a neutral decision making forum to determine human resource issues within the sector and to develop a sectoral human resources strategy."[127] Sector councils can provide a platform for cooperation between employers, workers (through unions), governments, and training institutions to ensure a given sector's labour and skills needs are met, and may be publicly co-funded.

Although there is a Canadian automotive sector council in the Canadian Automotive Partnership Council (CAPC), its mandate does not appear to include any communication or engagement with training institutions and/or service providers like AMTEC does.[128] Therefore, this report recommends strengthening the mandate and resources of the Talent and Skills Development sub-committee within CAPC to better identify and fill the gap between demand and supply of skilled talent. Additionally, training and education sector representatives, such as provincial ministers of education and/or colleges should be added to CAPC to help sustain a workforce development system that is innovative, responsive, and meets automotive, ZEV, and battery manufacturing industries' skill requirements. Incorporating this mandate into CAPC will reduce the duplication of work that would otherwise be needed if an entirely new Canadian version of AMTEC was created from scratch. Having this expanded and strengthened neutral collaborative forum for automotive suppliers, which are concentrated largely in Ontario and occupy a highly fragmented market with many different segments and small players,[129] could synergise sharing skills requirements, best practices, and resources to better prepare the skilled workers and their employers in this critical economic sector. This includes informing, and potentially even developing, education and training programs, as well as creating a central repository that provides information about the ZEV and battery manufacturing jobs and skills that are anticipated to be in higher demand in the future. While participation should be primarily voluntary, it should be made mandatory for any major investments that receive federal or provincial government investments.

Recommendation #2: Ensure new facilities that receive government support come with mandates for participation in CAPC.

A successful workforce transition is contingent on developing and sustaining skilled knowledge mobilization. Given the potential changes the sector and its workers are set to experience, greater participation and engagement between employers and their workforce should be embedded in any ZEV and battery manufacturing investments. Tier 1 and OEM investments above a certain threshold (i.e., expected to directly employ over 250 people) should have a mandate to engage in the expanded sector council model recommended above, with a specific need to join the sub-committee focused on talent and skills development. This would allow their skills needs to be shared with a wider group of stakeholders, including regional and local ESPs. ESPs can serve as community liaisons to ensure labour market information is made available to all who need it. Serving as the link between Tier 1 and OEMs, ESPs can also help ensure facilities have access to the skilled workers needed.

Recommendation #3: Lower barriers to entering the workforce and upskilling for workers with the necessary skills and interest to work throughout the ZEV supply chain.

There is a need to not just advertise to and attract new entrants into the automotive manufacturing labour force, but also to make it easier for them to get work in the sector, especially for those qualified immigrants with foreign credentials and experience. In addition to new entrants, steps should be taken to make it easier for current workers looking to move within the sector to do so. Given the need for more skilled journeypersons to train and supervise apprentices, as well as the overall need for skilled labour, two steps can be taken.

The first step gets at the previously identified difficulty of upskilling by getting a post-secondary qualification, which stakeholders mentioned is faced by apprentice training delivery agents (unions/employers). In this case, the pathway for those looking to do a post-secondary degree or diploma after an apprenticeship should be made easier. This could be addressed by forming a specific office under the joint auspices of the Ministry of Labour, Immigration Training and Skills Development and Ministry of Colleges and Universities, since the root of the issue mentioned by stakeholders was the administrative sharing of responsibilities between these ministries. Such a step would help create a more conducive environment to make skilled trades workers more adaptable to labour market shifts.

The second step is about making it easier for foreigners trained in science, technology, engineering, mathematics (STEM) and skilled trades fields relevant to the automotive manufacturing sector (including some engineering occupations) to get their provincial certificates of qualification as part of their immigration process.[130] The minimum cost of licensing for an immigrating skilled tradesperson is $235 before tax for all skilled trades regulated by Skilled Trades Ontario. This cost is for the Trade Equivalency Assessment, which allows an applicant with international trades experience and/or certification to sit for the Trades exam.[131] If successful with the exam, the applicant then has to pay another fee to get the Certificate of Qualification. That price however, is a minimum. A reassessment, which may be needed if the first application is rejected or if an applicant has new information that may help them qualify for a trade certification exam, comes with a separate fee. For engineering occupations that are regulated by Professional Engineers Ontario, the cost of assessment and/or certification as a professional engineer (P.Eng) starts at $406 after tax.[132] This cost is for those who want to practice in Ontario and is separate from the fee paid to have their foreign post-secondary degree recognized earlier on in the immigration process. The difficulty of immigrating to Canada through the designated programs for skilled workers (the Federal Skilled Worker Program and the Federal Skilled Trades Program), is further highlighted by the fact the latter has never reached its maximum capacity of applicants since its inception in 2013, with more tradespeople coming in through other streams instead.[133] Therefore, unifying or simplifying these fees may make it easier for qualified immigrant workers to enter the automotive manufacturing sector.

Recommendation #4: Create training programs that incorporate integration services for workers coming to Ontario from other parts of Canada, and outside of Canada.

Employers need more support in training and acculturating their newcomer and/or recent immigrant workers to Ontario industry standards and cultural nuances.[134] In one anecdote, employers mentioned workers not knowing they needed to come to work with closed-toe shoes on the shop floor because they were not used to doing that in their countries of origin. Given the importance of foreign workers to the talent pipeline in Ontario's automotive industry, their familiarization with the industry and its norms is imperative. This applies to recent international student graduates in Canada and newcomers/recent immigrants[135] to Canada.

For international student graduates, an example from Lambton College in Sarnia may provide a model to build on. In the Quality Engineering Management Graduate Certificate Program at Lambton, international students take a course called "Professional Communications" in their first semester that is designed to help them acculturate to Canadian workplace norms, business practices, and communication styles.[136] This is in addition to another course called "Workplace Health & Safety," which all students take and is supposed to give "an overview of Canadian labour laws, workplace rules and regulations Health and Safety Hazards…and various health & safety risks arising from a variety of occupations."[137] Having skilled trades and STEM programs across Ontario's PSIs incorporate something like this into their curricula may reduce the workload on employers when it comes to acculturating their new international student graduate recruits. This is especially important for those international students who complete only a post-graduate diploma or certificate in Ontario, which are often shorter than a full college or university undergraduate program and may not give the students as much time to acculturate compared to an undergraduate student who came to Ontario at a younger age.

Another example from the Sarnia area is the BASES training program run by a combination of local associations in the Sarnia-Lambton area, including the Sarnia-Lambton Industrial Educational Cooperative, Sarnia-Lambton Community Awareness and Emergency Response, and the Sarnia-Lambton Environmental Association under the Sarnia-Lambton Economic Partnership.[138] This program "…delivers safety training" on a "broad range of programs including Basic Safety Orientation… Respirator Fit Testing" and the like for plants, contractors, and building trades in the area (who are members of the Partnership).[139] In addition to the skills training, this co-op also helps with acculturation training for workers coming from other parts of Canada (e.g., oil sector workers moving from Alberta to Ontario). A program like this can be replicated across the regions previously mentioned in this report to account for local nuances and can be adjusted to also account for internationally experienced workers. Ultimately, it could become a recognized course or certification for newly hired international workers that ends with a regionally or, preferably, sectorally recognised certificate (micro-credential), signalling to employers that these workers have completed the basics. Something like this would help ease small and medium business employers' anxieties about overexerting themselves on this, as it would be done through an economic partnership, industry umbrella group, service provider, or a combination of all three.

Conclusion

The shift from ICEVs to ZEV and battery manufacturing is expected to have a significant impact on the labour market in Ontario. Investments in the province will create thousands of new jobs throughout the automotive manufacturing supply chain. This core and associated industry-wide shift presents opportunities and challenges, bringing uncertainty to manufacturers, as changes in technology and processes are impacting the skills and knowledge requirements of the labour force. Demand for STEM-educated workers and knowledge of software, electronics, and electrochemistry has increased. Many technical roles like mechanical and electrical engineers, software developers, and machine learning specialists are increasing in demand in Ontario's ZEV businesses. Skilled trades workers such as machinists, electricians, and many others are in demand as well, with such high demand that poaching employees has become a challenge for staff retention. Fully shifting away from combustion engines also means that, alongside the addition of new roles, existing workers will need to transition as their roles evolve. Although some displacement is inevitable, many existing workers possess transferable skills to aid the transition.

The best way Ontario, and Canada, can ensure communities and workers prosper amidst the transition from ICEVs to ZEVs is to continue to act boldly on regional investments and advance the ZEV and battery manufacturing sectors. The growth of this sector presents opportunities for the revival of the automotive industry, with good, high-quality careers for communities that support local economies. For some areas where rapid sectoral evolution and demand for higher-skilled workers is expected to be large, such as Windsor or London, ON, collaborative support from government, industry, and educational institutions will be needed to ensure that workers are prepared. Support for developing skills training and education programs capable of training individuals at scale will be critical. A multi-faceted focus on talent—sourcing new entrants and upskilling and retraining existing workers—will enable the province's ZEV and battery manufacturing sector to provide good, high-quality careers for communities to support local economies and foster a thriving automotive industry while moving towards a net-zero emissions future for the sector, region, and country.

Appendix 1: Description of methodologies used in this report

Real-Time Remote Access analysis

The analysis looks at sector-level jobs where sectors are defined using the North American Industry Classification System (NAICS). Sub-sectors traditionally included in the automotive industry are Motor vehicle parts manufacturing (NAICS 3363) and Motor vehicle assembly (NAICS 3361). However, this report's analysis broadened the definition of the industry to include producers in the supply chain that have previously been classified as non-automotive industries based on the portion of their sales coming from the traditional automotive sub-sectors. Industries that sell more than 1% of their output to the two traditional automotive sub-sectors were included in this analysis. 13 industry groups were identified and included in the analysis.

The sectoral-level data is then converted to occupational-level data using the Canadian National Occupational Classification (NOC) system. This is done by retrieving employment data for each NOC occupation employed within each of the NAICS 2-digit sub-sectors and their 4-digit industry groups. This dataset covers the 2021 Labour Force Survey, and was retrieved using Statistics Canada's Real-Time Remote Access (RTRA) Tool. This dataset provides details on which occupations are employed within each NAICS sub-sector as well as their employment levels in 2019. The employment numbers are used to provide shares for each sector as well as the weighting of each occupation in each sector.

Supply-chain mapping

The ZEV and battery manufacturing supply chain was determined from research and RTRA data analysis. NAICS code descriptors were used from the NAICS Canada 2022 Version 1.0 to position them within the identified supply chain.

Occupation Information Network (O*Net) analysis

Using data from the RTRA analysis, at the occupational level, the analysis develops a skills profile for each occupation using the O*NET database from the United States. The O*NET database offers detailed information about the importance of the usage of 35 skills and 33 knowledge in different occupations. This database provides an objective way to link the NOC to O*NET through a concordance table developed jointly by the Labour Market Information Council, Employment and Social Development Canada, and Statistics Canada. Using this concordance table, the standardized scores for "importance" are extracted for each NOC occupation. Using the weights of occupations and standardized scores for "importance" identified in each skills and knowledge profile, this analysis calculates the weighted average standardized score for each of the skills and knowledge based on the occupations in the relevant sectors. From this, the top five occupations were selected in each 2-digit NAICS sub-sector based on the highest employment levels to provide a snapshot of the skills and knowledge needed within the top occupations of the sub-sectors.

Foresight exercise

The foresight exercise was a combination of informal interviews, a survey, and two in-person workshops to help understand where stakeholders anticipated the industry is going. For the informal interviews, 16 interviews were conducted with a variety of stakeholders, including educational institutions, industry associations, unions, and think tanks. Additionally, for the survey, respondents were asked to select one of three scenarios they thought would be most likely to occur in the ZEV and battery manufacturing sector between now and 2030. The scenarios were as follows:

Scenario 1: High growth

- Very high investment into original equipment manufacturers (OEMs) and battery manufacturing plants.
- Clear policy pathways for development of critical minerals and mining capacity.
- Abundance of skilled professionals and training opportunities.

Scenario 2: Medium growth

- Relatively lower levels of investment in OEMs and battery manufacturing.
- Lack of clear critical mineral policies muddies pathway for establishing domestic battery hub.
- Some retraining and reskilling opportunities to meet increased demand, but labour shortages remain.

Scenario 3: Low growth

- Very low levels of additional investment in the OEM and battery sectors.
- Lack of clear critical mineral policies muddies pathway for establishing domestic battery hub.
- Labour shortages and limited retraining and skilling opportunities inhibit growth of industry and deter future investments.

Survey respondents comprised auto assembly/OEMs (12.8%) auto parts manufacturers (20%); academia/think tanks/training institutions (20.5%); battery cell, pack and module manufacturers (7.7%); labour union representatives and chiefs (7.7%); and sectoral/umbrella body representatives (30.8%). They were presented with a range of questions to answer that were specific to their industry area and focused on the recruitment of workers, current context, and beliefs about the future of the sector out to 2030.

For the workshops, two in-person workshops were held, bringing together a range of stakeholders to discuss the future of ZEV and battery manufacturing. The first workshop was held in Windsor, ON, and partnered with Workforce WindsorEssex and Invest WindsorEssex to focus on the region's evolution as a battery manufacturing hub. The second workshop was held in London, ON, supported by the London Economic Development Corporation (LEDC) and the London Region Manufacturing Council (LRMC) specifically focusing on the Opportunities and Challenges of a ZEV transition in Southern Ontario. Both workshops involved breakout sessions among the attendees, which were recorded.

Appendix 2: Industries and occupations included within this current skills analysis

NAICS code	Sub-sector	Industry group	NOC titles
3311	Primary metal manufacturing	Iron and steel mills and ferro-alloy manufacturing	• Supervisors, mineral and metal processing • Labourers in mineral and metal processing • Crane operators • Machine operators, mineral and metal processing • Construction millwrights and industrial mechanics
3312	Primary metal manufacturing	Steel product manufacturing from purchased steel	
3315	Primary metal manufacturing	Foundries	
3261	Plastics and rubber products manufacturing	Plastic product manufacturing	• Supervisors, plastic and rubber products manufacturing • Labourers in rubber and plastic products manufacturing • Mixing machine operators, plastics processing • Calendering process operators, plastics processing • Extruding process operators, plastics processing
3262	Plastics and rubber products manufacturing	Rubber product manufacturing	
3272	Non-metallic mineral product manufacturing	Glass and glass product manufacturing	• Manufacturing managers • Industrial instrument technicians and mechanics • Labourers in mineral and metal processing • Industrial engineering and manufacturing technologists • Glass process control operators
3323	Fabricated metal product manufacturing	Architectural and structural metals manufacturing	• Machinists • Manufacturing managers • Supervisors, other mechanical and metal products manufacturing • Labourers in metal fabrication • Welders
3327	Fabricated metal product manufacturing	Machine shops, turned product, and screw, nut and bolt manufacturing	
3342	Computer and electronic product manufacturing	Communications Equipment Manufacturing	• User support technicians • Supervisors, electronics manufacturing • Supervisors, supply chain, tracking and scheduling co-ordination occupations • Electronics assemblers • Electronics inspectors
3344	Computer and electronic product manufacturing	Semiconductor and other electronic component manufacturing	
3359	Electrical equipment, appliance and component manufacturing	Other electrical equipment and component manufacturing	• Supervisors, electrical products manufacturing • Shippers and receivers • Other labourers in processing, manufacturing and utilities • Other metal products machine operators • Machine operators, electrical apparatus manufacturing
3361	Transportation equipment manufacturing	Motor vehicle manufacturing	• Other metal products machine operators • Motor vehicle assemblers • Motor vehicle inspectors and testers • Supervisors, motor vehicle assembling • Metalworking machine operators
3363	Transportation equipment manufacturing	Motor vehicle parts manufacturing	

Appendix 3: O*NET Skills and knowledge Classification

This section is adapted from the report *Jobs and Skills in the Transition to a Net Zero Economy: A Foresight Exercise* by Atiq et al. (2022),[140] which compiles skills and knowledge importance ratings for the 35 skills and 33 knowledge that are part of the O*NET Database. Skills are proficiencies that are developed through training or experience. The 35 skills are divided into basic skills and cross-functional skills. Basic skills facilitate the acquisition of new knowledge and are further divided into content and process skills. Cross-functional skills extend across several domains of activities. Knowledge also extends across several subject topics. Overall, these 35 skills are grouped into seven categories, and the 33 knowledge elements are grouped into ten categories, as outlined in the tables below.

Basic skills

Developed capacities that facilitate learning or the more rapid acquisition of knowledge.

Sub-categories	Skill details
Content: Background structures needed to work with and acquire more specific skills in a variety of different domains.	• **Active listening:** Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times. • **Mathematics:** Using mathematics to solve problems. • **Reading comprehension:** Understanding written sentences and paragraphs in work-related documents. • **Science:** Using scientific rules and methods to solve problems. • **Speaking:** Talking to others to convey information effectively. • **Writing:** Communicating effectively in writing as appropriate for the needs of the audience.
Process: Procedures that contribute to the more rapid acquisition of knowledge and skill across a variety of domains.	• **Active learning:** Understanding the implications of new information for both current and future problem solving and decision making. • **Critical thinking:** Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions, or approaches to problems. • **Learning strategies:** Selecting and using training/instructional methods and procedures appropriate for the situation when learning or teaching new things. • **Monitoring:** Monitoring/assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.

Cross-functional skills

Developed capacities that facilitate the performance of activities that occur across jobs.

Sub-categories	Skill details
Complex problem solving skills: Developed capacities used to solve novel, ill-defined problems in complex, real-world settings.	• **Complex problem solving:** Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
Resource management skills: Developed capacities used to allocate resources efficiently.	• **Management of financial resources:** Determining how money will be spent to get the work done, and accounting for these expenditures. • **Management of material resources:** Obtaining and seeing to the appropriate use of equipment, facilities, and materials needed to do certain work. • **Management of personnel resources:** Motivating, developing, and directing people as they work, identifying the best people for the job. • **Time management:** Managing one's own time and the time of others.
Social skills: Developed capacities used to work with people to achieve goals.	• **Coordination:** Adjusting actions in relation to others' actions. • **Instructing:** Teaching others how to do something. • **Negotiation:** Bringing others together and trying to reconcile differences. • **Persuasion:** Persuading others to change their minds or behavior. • **Service orientation:** Actively looking for ways to help people. • **Social perceptiveness:** Being aware of others' reactions and understanding why they react as they do.
Systems skills: Developed capacities used to understand, monitor, and improve socio-technical systems.	• **Judgment and decision making:** Considering the relative costs and benefits of potential actions to choose the most appropriate one. • **Systems analysis:** Determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes. • **Systems evaluation:** Identifying measures or indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.
Technical skills: Developed capacities used to design, set-up, operate, and correct malfunctions involving application of machines or technological systems.	• **Equipment maintenance:** Performing routine maintenance on equipment and determining when and what kind of maintenance is needed. • **Equipment selection:** Determining the kind of tools and equipment needed to do a job. • **Installation:** Installing equipment, machines, wiring, or programs to meet specifications. • **Operation and control:** Controlling operations of equipment or systems. • **Operations analysis:** Analyzing needs and product requirements to create a design. • **Operations monitoring:** Watching gauges, dials, or other indicators to make sure a machine is working properly. • **Programming:** Writing computer programs for various purposes. • **Quality control analysis:** Conducting tests and inspections of products, services, or processes to evaluate quality or performance. • **Repairing:** Repairing machines or systems using the needed tools. • **Technology design:** Generating or adapting equipment and technology to serve user needs. • **Troubleshooting:** Determining causes of operating errors and deciding what to do about it.

Knowledge

Organized sets of principles and facts that apply to a wide range of situations.

Sub-categories	Knowledge details
Arts and humanities: Knowledge of facts and principles related to the branches of learning concerned with human thought, language, and the arts.	• **English language:** Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar. • **Fine arts:** Knowledge of the theory and techniques required to compose, produce, and perform works of music, dance, visual arts, drama, and sculpture. • **Foreign language:** Knowledge of the structure and content of a foreign (non-English) language including the meaning and spelling of words, rules of composition and grammar, and pronunciation. • **History and archeology:** Knowledge of historical events and their causes, indicators, and effects on civilizations and cultures. • **Philosophy and theology:** Knowledge of different philosophical systems and religions. This includes their basic principles, values, ethics, ways of thinking, customs, practices, and their impact on human culture.
Business and management: Knowledge of principles and facts related to business administration and accounting, human and material resource management in organizations, sales and marketing, economics, and office information and organizing systems.	• **Administration and management:** Knowledge of business and management principles involved in strategic planning, resource allocation, human resources modeling, leadership technique, production methods, and coordination of people and resources. • **Administrative:** Knowledge of administrative and office procedures and systems such as word processing, managing files and records, stenography and transcription, designing forms, and workplace terminology. • **Customer and personal service:** Knowledge of principles and processes for providing customer and personal services. This includes customer needs assessment, meeting quality standards for services, and evaluation of customer satisfaction. • **Economics and accounting:** Knowledge of economic and accounting principles and practices, the financial markets, banking, and the analysis and reporting of financial data. • **Personnel and human resources:** Knowledge of principles and procedures for personnel recruitment, selection, training, compensation and benefits, labor relations and negotiation, and personnel information systems. • **Sales and marketing:** Knowledge of principles and methods for showing, promoting, and selling products or services. This includes marketing strategy and tactics, product demonstration, sales techniques, and sales control systems.
Communications: Knowledge of the science and art of delivering information.	• **Communications and media:** Knowledge of media production, communication, and dissemination techniques and methods. This includes alternative ways to inform and entertain via written, oral, and visual media. • **Telecommunications:** Knowledge of transmission, broadcasting, switching, control, and operation of telecommunications systems.
Education and training: Knowledge of principles and methods for curriculum and training design, teaching and instruction for individuals and groups, and the measurement of training effects.	• **Education and training:** Knowledge of principles and methods for curriculum and training design, teaching and instruction for individuals and groups, and the measurement of training effects.
Engineering and technology: Knowledge of the design, development, and application of technology for specific purposes.	• **Building and construction:** Knowledge of materials, methods, and the tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads. • **Computers and electronics:** Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming. • **Design:** Knowledge of design techniques, tools, and principles involved in production of precision technical plans, blueprints, drawings, and models. • **Engineering and technology:** Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services. • **Mechanical:** Knowledge of machines and tools, including their designs, uses, repair, and maintenance.

Sub-categories	Knowledge details
Health services: Knowledge of principles and facts regarding diagnosing, curing, and preventing disease, and improving and preserving physical and mental health and well-being.	• **Medicine and dentistry:** Knowledge of the information and techniques needed to diagnose and treat human injuries, diseases, and deformities. This includes symptoms, treatment alternatives, drug properties and interactions, and preventive health-care measures. • **Therapy and counseling:** Knowledge of principles, methods, and procedures for diagnosis, treatment, and rehabilitation of physical and mental dysfunctions, and for career counseling and guidance.
Law and public safety: Knowledge of regulations and methods for maintaining people and property free from danger, injury, or damage; the rules of public conduct established and enforced by legislation, and the political process establishing such rules.	• **Law and government:** Knowledge of laws, legal codes, court procedures, precedents, government regulations, executive orders, agency rules, and the democratic political process. • **Public safety and security:** Knowledge of relevant equipment, policies, procedures, and strategies to promote effective local, state, or national security operations for the protection of people, data, property, and institutions.
Manufacturing and production: Knowledge of principles and facts related to the production, processing, storage, and distribution of manufactured and agricultural goods.	• **Food production:** Knowledge of techniques and equipment for planting, growing, and harvesting food products (both plant and animal) for consumption, including storage/handling techniques. • **Production and processing:** Knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacture and distribution of goods.
Mathematics and science: Knowledge of the history, theories, methods, and applications of the physical, biological, social, mathematical, and geography.	• **Biology:** Knowledge of plant and animal organisms, their tissues, cells, functions, interdependencies, and interactions with each other and the environment. • **Chemistry:** Knowledge of the chemical composition, structure, and properties of substances and of the chemical processes and transformations that they undergo. This includes uses of chemicals and their interactions, danger signs, production techniques, and disposal methods. • **Geography:** Knowledge of principles and methods for describing the features of land, sea, and air masses, including their physical characteristics, locations, interrelationships, and distribution of plant, animal, and human life. • **Mathematics:** Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications. • **Physics:** Knowledge and prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic and sub-atomic structures and processes. • **Psychology:** Knowledge of human behavior and performance; individual differences in ability, personality, and interests; learning and motivation; psychological research methods; and the assessment and treatment of behavioral and affective disorders. • **Sociology and anthropology:** Knowledge of group behavior and dynamics, societal trends and influences, human migrations, ethnicity, cultures, and their history and origins.
Transportation: Knowledge of principles and methods for moving people or goods by air, rail, sea, or road, including the relative costs and benefits.	• **Transportation:** Knowledge of principles and methods for moving people or goods by air, rail, sea, or road, including the relative costs and benefits.

Appendix 4: Assumptions and limitations

It is essential to recognise that this is a foresight exercise and not a forecasting exercise. There are limitations to the methodology chosen: biases of sampling and non-response; and survey sample size. Firstly, the sampling bias occurs because of the research project's scope. Although the place-based approach helps generate customizable and specific solutions while also shining a light on specific regions' issues, our project and analysis leave out developments in Quebec, where significant mining and battery production activities have taken place. Secondly, perhaps due to the length of our survey, or simply our desired respondents not having any knowledge of the PLACE Centre or Smart Prosperity Institute, a lot of surveys sent out went unanswered, creating a non-response bias. As such, there were higher levels of participation from stakeholders who might be more inclined or familiar with answering a survey or have more frequent access to a computer (academics, sector representatives, lobbyists, directors, and other executives) compared to labour union or floor representatives. The survey sample size can always be bigger, especially when doing a detailed analysis of a major sector like manufacturing. Furthermore, some of the survey respondents were also our workshop attendees. So, while the quality of responses received across interviews, surveys, and workshops was exceptional, there could have been more quantity.

There were also limitations of the skills and knowledge analysis. The analysis is based on the 35 skills and 33 knowledge identified in the United States' O*NET database. This has some drawbacks. It is important to recognise that these skills and knowledge elements are static in nature. Future changes in the importance of the skills and knowledge will change the outcomes of this analysis. Relying on O*Net classification also has potential shortcomings:

1. the classification is made up of conceptual ideas and general descriptions which cannot convey other details that might be important to understand, such as on-the-job skills that employers look for when making hiring decisions;
2. the O*NET skills and knowledge ratings reflect averages across automotive sector relevant occupations in Ontario, regardless of geographic location or employing industry and are therefore not necessarily specific to the ZEV and battery manufacturing sector.

Additionally, the assumption was made that the skills and knowledge ratings, while applicable for the automotive sector in Ontario, would be the same for the ZEV and battery manufacturing sector.

Finally, the top occupations in each sub-sector were selected based on the highest employment levels and therefore, assumed to be the occupations that could face the biggest changes during the transition to ZEVs.

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