Jobs and Skills in the Transition to a Net-Zero Economy

A Foresight Exercise

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Contents

List of Abbreviations i

Executive Summary ii

SECTION 1:
Introduction 1

SECTION 2:
Impact of a Net-Zero Transition on Labour Markets 8

SECTION 3:
Methodology 12

SECTION 4:
Decarbonization Scenarios 17

SECTION 5:
Analysis of Results 22

SECTION 6:
Skills in a Decarbonized Economy 36

SECTION 7:
Conclusions and Recommendations 63

SECTION 8:
Potential Avenues for Future Research 69

References 71

Appendices 78

List of Abbreviations

bbl	Barrel of crude oil
BTU	British thermal unit
CCS	Carbon capture and storage
CCUS	Carbon capture utilization and storage
Cedefop	European Centre for the Development of Vocational Training
CCI	Canadian Climate Institute
CGE	Computable general equilibrium
CLS	Canadian Light Sweet
CO_2	Carbon dioxide
DAC	Direct air capture
ECO Canada	Environmental Careers Organization Canada
ECT	Environment and Clean Technology
ESDC	Employment and Social Development Canada
ETS	Emissions trading system
EU	European Union
EU ETS	EU Emissions Trading System
GDP	Gross domestic product
GHG	Greenhouse gas
ILO	International Labour Organization
IOE	International Organization of Employers
IRENA	International Renewable Energy Agency
ITUC	International Trade Union Confederation
LFS	Labour Force Survey
LMIC	Labour Market Information Council
$MtCO_2e$	Megatonnes of carbon dioxide equivalent
MW	Megawatt
NAICS	North American Industry Classification System
NOC	National Occupational Classification
OECD	Organisation for Economic Co-operation and Development
O*NET	Occupation Information Network
PBO	Parliamentary Budget Officer
PJ	Petajoule
UNEP	United Nations Environment Program
U.S.	United States of America
WASS	Weighted average standardized score
WCS	Western Canadian Select
WTI	West Texas Intermediate

Executive Summary

Canada has committed to achieving net-zero greenhouse gas emissions by the year 2050. What implications will this have on jobs and the skills needed for those jobs?

There is a growing consensus on the benefits of transitioning to a net-zero economy beyond simply controlling global temperature rises. These are often referred to as co-benefits, and a significant one is job creation. Jobs are created through a net-zero transition as a result of changes in technologies and demand, modes of production, macroeconomic conditions, and international trade. While the transition's overall impact on jobs is expected to be positive, it will be spread unevenly across sectors. The business case for a decarbonized economy rests on the successful transition of workers from jobs expected to disappear to those that will emerge and grow. The questions that follow have to do with how these changing jobs across sectors will affect the demand for skills and how policy-makers should respond by creating skills policy that enables clean and resilient growth across a range of net-zero emissions futures.[1]

To answer these questions, this report presents a foresight exercise that models the jobs and skills that would be required in a net-zero economy across a set of distinct futures. There are many ways that Canada could reach net-zero emissions. In this report, we consider three:

> A lower-carbon-intensity pathway with high rates of fuel switching in favour of end-use electrification

> A higher-carbon-intensity pathway that relies less on fuel switching and more on carbon capture or direct air capture (DAC) technologies

1 In this report, skills are defined as proficiencies developed through training or experience. The 35 skills used for the analysis are from the United States Department of Labor's O*NET Database, which are further categorized into seven skill groups: content, process, social, complex problem solving, technical, systems, and resource management.

> A middle-ground that contains elements of both and a greater reliance on carbon offsets

While all three pathways take us to a net-zero emissions goal by 2050, the key features varying across these scenarios are the stringency of greenhouse gas (GHG) emissions reduction policies, market conditions, and technology parameters. Other co-benefits of reducing emissions (which are not modelled here) include improved health outcomes, higher resource efficiency, reduced air pollution, technological innovation and spillovers, as well as better distributional impacts (Deng et al., 2017) (see Box 2 on pages 25-26).

The model utilized in this foresight analysis offers several benefits, including identifying changes in the number of jobs created across sectors and scenarios due to different pathways to decarbonization. Even so, as with all modelling exercises, the assumptions that give the model its power also limit the accuracy of its results. Yet, while it is important to acknowledge those limitations (see Appendix 1), the contours of the three potential decarbonization pathways sketched out by the model provide valuable information. Indeed, this modelling provides policy-makers and stakeholders from across the skills development ecosystem with a critical starting point for formulating the policies and programs that will be needed to support Canadians as we make the unprecedented economic changes required to mitigate and adapt to climate change.

This report presents a foresight analysis that was designed to explore multiple plausible futures for the purpose of assisting in the formulation of policy approaches that are resilient in the face of uncertainty.

This report presents a foresight analysis that was designed to explore multiple plausible futures for the purpose of assisting in the formulation of policy approaches that are resilient in the face of uncertainty. Critically, this report does not seek to forecast the future.[2] Forecasting the future is essentially impossible at this time, largely due to the considerable uncertainty over the actual decarbonization pathway that Canada might take in the long run, alongside uncertainties around demographic change, technological change, and global trends. Foresight exercises, such as this one, and the plausible futures they generate, can be especially helpful to policy-makers and stakeholders in the education ecosystem as they seek to develop policies and programs that are robust and resilient. Specifically, the foresight results reveal several similarities across all three pathways to a net-zero future:

2 Unlike foresight exercises, forecasting exercises aim to predict the future based on past and current trends and data.

1. **Decarbonization has little impact on employment in the majority of sectors.** The growth of fully 75% of jobs in the economy is not directly affected by these decarbonization scenarios because they are in sectors that are neither energy-intensive nor GHG-intensive (e.g., retail, finance, healthcare, education, and services).

2. **Job creation and economic growth continue in all three scenarios.** Across all three scenarios, modelling using the gTech—a dynamic computable general equilibrium (CGE) model of the North American economy maintained by Navius Research Inc.—shows that Canada's economy continues to grow between 2015 and 2050. Across scenarios that are more reliant on carbon as well as those that are less reliant on carbon, the Canadian economy continues to add jobs, with a difference of only 113,000 jobs separating the scenario with the highest jobs estimate from the scenario with the lowest jobs estimate. In fact, the scenario with the strongest projected job growth is actually the scenario with the most aggressive carbon-reduction pathway.

3. **Job creation is unevenly distributed across sectors.** Relative to 2015, all decarbonization pathways result in higher numbers of jobs in sectors like manufacturing and construction. However, resource-intensive sectors, like agriculture and oil and gas, will experience decelerated job growth or outright job declines. It should be noted that this analysis did not account for the job creation potential of carbon offset schemes, which are likely to preserve or create jobs in the agriculture sector (see Box 4).[3]

These impacts on jobs across different sectors and scenarios lead to five key insights for skills requirements:

1. **Non-technical skills are as important as, if not more important than, technical skills in a net-zero green transition.** Even where technical skills like operations monitoring and quality control are necessary, the score for importance of non-technical skills is higher. This does not render technical skills inconsequential, but underscores the importance of broad-based skills profiles needed for jobs in a decarbonized future. In fact, technical skills combine with non-technical skills to form "green literacy," which is essential for the workforce in a low-carbon future.

2. **Social and cognitive skills are vital.** The top five skills that rank as fundamental for the workforce in a decarbonized future are critical thinking, monitoring, coordination, judgement and decision making, and complex problem solving.

3 This is a policy assumption external to the model that is not accounted for in the model. It was built into the scenario because we expect Canada's decarbonization pathways to rely, to a certain extent, on carbon offset schemes. However, there is still a lot of uncertainty around the contours of such schemes, both domestically and internationally, with the United Nations Framework Convention on Climate Change still in the process of defining international schemes.

Top skills in sectors expected to lose jobs are largely the same as the top skills for jobs in sectors expected to grow, meaning that workers who may lose jobs will largely possess the skills needed for jobs that will emerge across a range of decarbonized futures.

3. **A number of existing skills, recycled in a strategic way, are imperative for tasks relevant in a net-zero economy.** Existing non-technical and technical skills—like critical thinking, problem solving, management, operations monitoring, and quality control—that stand out in this analysis are not unique. Rather, they are existing skills used across a range of lower-carbon-intensity and higher-carbon-intensity jobs. A future characterized by net-zero carbon jobs will require the application of these skills in ways that allow transitioning workers and new workers joining the labour force to adapt processes, technologies, and services to conform with environmental regulation.

4. **Workers across provinces have different skills development needs as they transition.** Those in resource-dependent regions are particularly vulnerable to this transition as resource jobs are likely to decline in all the three decarbonization pathways modelled for this analysis. However, these losses would be offset through job growth in other sectors, implying that one way to support these workers would be to provide skills training that allows workers from the oil and gas sectors to transition to greener occupations.

5. **Sectors that gain jobs and those that lose jobs both have common skills needs.** Top skills for jobs in animal production, farming, and oil and gas extraction—sectors expected to lose jobs—are critical thinking, monitoring, problem solving, coordination, decision making, and time management. These are largely the same as the top skills for jobs in sectors expected to grow, meaning that workers who may lose jobs will largely possess the skills needed for jobs that will emerge across a range of decarbonized futures. This highlights the importance of tackling already-existing challenges faced by employers in recognizing and transferring common skillsets across occupations. Fully leveraging common skillsets across occupations will require deeper solutions around skills identification and recognition of credentials that allow for skills transferability.

Coordinated action is required by policy-makers, educational institutions, and employers to support a smoother transition of workers from one set of opportunities to another. This report identifies a few recommendations for developing skills policies to respond to Canada's net-zero commitments, including:

1. **Developing a net-zero career roadmap based on bridging labour market information and data gaps.** This roadmap should include a central repository of careers that are central to a net-zero transition linked to a database of skills, similar to the Occupational Information Network (O*NET) in the United States, that reflects scores for the context of the Canadian green transition.

2. **Designing reskilling and upskilling programs that respond to changing demographics, including provincial programs for workers in transition.** Such programs would respond to the specific needs of older workers, new graduates, and foreign-educated workers. They would also be regionally differentiated to ensure the needs of, for instance, oil and gas workers in Alberta are not inadvertently assumed to be identical to those of manufacturing workers in Ontario and Quebec.

3. **Undertaking training programs that underscore the importance of social and cognitive skills for future work.** These include critical thinking, active learning, coordination, social perceptiveness, monitoring, and complex problem solving, which have traditionally been developed through "on-the-job" training. Skills training programs and national curricula need to mainstream a social skills component. Additionally, the success of current efforts by employers to upskill and reskill their employees can be supported by building performance measurement frameworks (Cukier, 2020).

4. **Fostering a skills ecosystem that is based on a set of horizontal and vertical partnerships and mainstreams career considerations aligned with net-zero emissions scenarios.** Efforts to develop such a system must include stakeholders who create and fund environmental policy, such as federal and provincial environmental and clean technology departments. Horizontal and vertical partnerships between the federal and provincial governments, provincial skills organizations, and educational institutes will also be critical to supporting regional upskilling and reskilling needs.

5. **Developing mechanisms that support workers to help reduce the unemployment and underemployment created by the transition.** These can include extended financial support to help meet the evolving requirements of workers in transition. They can also include investments that identify areas of high job growth at a regional or community level and connect employers with training organizations to accelerate upskilling and reskilling efforts.

SECTION 1:
Introduction

There is growing consensus on the benefits of transitioning to net-zero greenhouse gas (GHG) emissions, or a net-zero economy, beyond those pertaining to controlling global temperature rises. These are usually referred to as co-benefits, and job creation is one additional benefit offered by such a transition. According to the International Labour Organization (ILO) (2018), changes in energy production and consumption to achieve the goal of limiting warming to 2°C could lead to the net creation of about 18 million jobs globally. A successful transition to a decarbonized economy is not only critical for the climate, it is also good for labour markets in countries around the world, including in Canada. Bridge & Gilbert (2017) estimate that the transition to a net-zero economy will create 3.3 million direct jobs in the building trades alone by 2050. Moreover, recovery efforts following the COVID-19 pandemic have highlighted the need for unprecedented levels of spending, which will prove transformative if these efforts are aligned with Canada's decarbonization commitments (Corkal et al., 2020).

This report presents a foresight exercise that models the number of jobs created and the associated skills implications in a net-zero economy across a set of distinct futures.

To begin to understand the quantitative impact on the labour market of achieving net-zero GHG emissions, this report presents a foresight exercise that models the number of jobs created and the associated skills implications in a net-zero economy across a set of distinct futures. While several studies show that the transition will have an overall positive effect on employment, there is considerable variation in the impacts across sectors and occupations. A net-zero transition will create new jobs in some sectors, lead to job losses in others, and change the nature of existing jobs (Martinez-Fernandez et al., 2013).

There are many ways that Canada could reach net-zero emissions. This report considers three key potential pathways:

1. A lower-carbon-intensity pathway with high rates of fuel switching in favour of end-use electrification

2. A higher-carbon-intensity pathway that relies less on fuel switching and more on carbon capture or direct air capture (DAC) technologies

3. A middle-ground that contains elements of both and a greater reliance on carbon offsets

While all three pathways take us to a net-zero emissions goal by 2050, the key features varying across these scenarios are the stringency of GHG emissions reduction policies, market conditions, and technology parameters. Other co-benefits of reducing emissions, which are not modelled here, include improved health outcomes, higher resource efficiency, reduced air pollution, technological innovation and spillovers, as well as better distributional impacts (Deng et al., 2017) (see Box 2 on pages 25-26).

The model utilized in this foresight analysis offers several benefits, including identifying changes in the number of jobs created across sectors and scenarios due to different pathways to decarbonization. Even so, as with all modelling exercises, the assumptions that give the model its power also limit the accuracy of its results. Yet, while it is important to acknowledge those limitations (see Appendix 1), the contours of the three potential decarbonization pathways sketched out by the model provide valuable information. Indeed, this modelling provides policy-makers and stakeholders from across the skills development ecosystem with a critical starting point for formulating the policies and programs that will be needed to support Canadians as we make the unprecedented economic changes required to mitigate and adapt to climate change.

Our analysis begins with an examination of the jobs and skills that would be required in a net-zero Canadian economy across a set of distinct plausible futures. As such, it presents a foresight analysis designed to assist the formulation of policy approaches that are resilient in the face of uncertainty. Critically, this report does not seek to forecast the future.[4] Indeed, forecasting the future is essentially impossible at this time, largely due to the considerable uncertainty over the actual decarbonization pathway that Canada might take in the long run. In addition, forecasting the future is also generally difficult because of the uncertainty around demographic and technological changes and global trends that will impact Canada's economic future and decarbonization trajectories. These uncertainties also include the potential threats and opportunities that may emerge across sectors, impacting the labour market for both existing workers and new entrants.

Despite this uncertainty, our analysis suggests that successfully navigating the changes involved in decarbonization will depend on transitioning workers "between sectors" (from those expected to shrink

4 Unlike foresight exercises, forecasting exercises have the aim of predicting the future based on past and current trends and data.

to those expected to grow) and "within sectors" (via reskilling and upskilling). Skills development policies will play a crucial role in these transitions (OECD, 2012), and underestimating this role risks creating bottlenecks, raising unemployment, and slowing long-run economic growth. All of this amplifies the need to develop broad-based education and skills development programs for transitioning workers as well as new entrants. The second half of our analysis focuses on understanding the skills needs generated by the economic changes involved in decarbonization. That analysis aims to help policy-makers and other skills development and education ecosystem stakeholders build the critical policy and programming infrastructure that will be needed to support and enable existing and future workers to thrive as our economy decarbonizes.

Setting the stage: Canada's net-zero economy commitments

Since 2016, Canada's drive toward a net-zero economy has largely been shaped by the Pan-Canadian Framework on Clean Growth and Climate Change (Environment and Climate Change Canada, 2016). These measures support Canada's 2030 goal of reducing GHG emissions to 30% below 2005 levels. More recently, the Government of Canada solidified its commitments to a net-zero economy. In November 2020, the Canadian Net-Zero Emissions Accountability Act was passed to legally bind the Government of Canada to achieve net-zero emissions by 2050. The Act established five-year emissions reduction targets, requiring plans to reach them and reports on progress. An independent advisory body will guide the Government of Canada through its pathway to net-zero. Building on this commitment, in December 2020, the Government of Canada released its comprehensive plan to combat climate change, *A Healthy Environment and a Healthy Economy.* The new climate plan is based on five pillars:

> Cutting energy waste

> Making clean transportation and power affordable and accessible

> Putting a price on carbon pollution

> Building a clean industrial advantage

> Adopting nature-based solutions

The Climate Plan includes 64 new policies and programs and $15 billion in investment on top of the Canada Infrastructure Bank's $6 billion in financing for clean infrastructure (Environment and Climate Change Canada, 2020). Leveraging some of this momentum, in July 2021, the federal government committed to the even more ambitious target of cutting Canada's emissions by 40 to 45% of 2005 levels by 2030.[5]

5 While the analysis in this report was conducted prior to the commitment to these new 2030 targets, it is still consistent with the end goal of net-zero emissions by 2050. As such, the change in 2030 targets might only impact jobs, to a limited extent, in the initial years of the modelling up to and around the year 2030.

Key drivers of net-zero aligned employment and skills

Between 2015 and 2019, jobs in the environment and clean technology (ECT) sector in Canada increased from 313,250 to 338,695 (average annual growth rate of 1.97%), making up approximately 1.8% of all jobs in the country. Out of these, the largest chunk (22%) of these jobs was in the utilities sector, predominantly in electric power generation, transmission, and distribution. This was followed by the engineering construction sector with 19% of jobs, the services sector with 15% of jobs, and the manufacturing sector with 12% of jobs (Statistics Canada, 2021).

The employment trends in the ECT sector are driven by a range of technical, economic, and policy factors. Technological innovation is a major factor as it improves efficiency, lowers costs, drives usage, and ultimately changes jobs and skill requirements (IRENA, 2018). However, the impact of technological innovation on jobs and skills is not uniform and varies across sectors.

Another driver is energy and environmental policy (via regulatory and public policy incentive schemes) (Cedefop, 2012). These policies:

> Set the overall goal and standards for the medium and long run

> Provide funding and infrastructure support for innovative net-zero aligned projects

> Create and maintain a level playing field for all stakeholders[6]

According to Cedefop (2019), carbon emissions reduction policies are among the most impactful policies operating in the ECT sector labour market. Decarbonization pathways are largely determined by relative costs, investment decisions, technological innovation, and environmental policies, which, in turn, affect the labour market. This is especially true for skills in net-zero jobs, which are defined as proficiencies needed by workers across all sectors and levels to help adapt products, processes, and services to the changing climate and to conform to environmental requirements (Martinez-Fernandez et al., 2013).

Technology and policies drive the demand for jobs and skills. The supply is mainly determined by the strength of institutional frameworks and skills ecosystems. The jobs and skills relevant for a net-zero economy are still being identified as climate policies translate into investments. Training institutions are only beginning to understand the implications of transitioning to net-zero economies and need to respond by changing their curricula and skills training initiatives to a greater extent than they have done so far (Martinez-Fernandez et al., 2013). This report adds to this discussion and supports these types of changes by identifying the skills needed by workers in a decarbonized economy.

6 Forward-thinking public policies are also key to support different stages of the clean innovation system and well-functioning markets (Elgie & Brownlee, 2017).

Jobs and skills in a decarbonized Canada

Decarbonization will directly affect jobs through various channels (see Box 1 on page 7). However, the resulting impact on the demand for skills is still unclear. Studies conducted over the years conclude that jobs in a decarbonized economy, new and old, will vary in their skills requirements. Most jobs will require a mix of generic skills associated with familiar occupations (project management, problem solving, mathematical skills). Some new net-zero jobs will emerge, which will require new combinations of skills (e.g., technical skills in renewables combined with communication skills) (OECD, 2012). Therefore, there is a need to better understand how the demand for skills will be impacted across decarbonization scenarios.

This report models three credible but distinct decarbonization pathways, using a computable general equilibrium (CGE) model of the North American economy, the gTech, housed at Navius Research Inc. The first pathway is a lower-carbon-intensity pathway, referred to as *Electrons*, in which fossil fuels are rapidly switched out for end-use electrification. The second pathway is a higher-carbon-intensity pathway that is referred to as *Resources*, which entails less fuel switching and greater reliance on carbon capture or direct air capture (DAC). The third pathway combines a mix of the first two pathways and is referred to as *Blended*. In all cases, the net-zero emissions goal is assumed to be achieved by 2050.[7] The key features varying across the three scenarios are the stringency of GHG emissions reduction policies, market conditions, and available technologies.

The objective of this report is twofold: first, through modelling, to understand the different configurations of employment in the Canadian economy that correspond to our three decarbonization pathways; second, and based on these projections, to assess the skills implications of the cross-sectoral job gains and losses, accounting for current industry classifications and employment data. To date, much of the debate in Canada has focused on reducing carbon emissions. However, little work has been done on projecting the cross-sectoral and provincial jobs implications of a green transition, let alone identifying the associated skills implications. This report aims to bridge that

There is a need to better understand how the demand for skills will be impacted across decarbonization scenarios.

7 The Blended pathway achieves 75% of emissions reduction with the rest of the emissions being offset elsewhere. Carbon offsets are instruments that reduce GHGs to compensate for emissions made in other geographic locations.

gap and provide insights on the technical and social skills that will be necessary for this transition, regardless of the pathway Canada follows to reach net-zero.

The rest of the report is structured as follows. Section 3 reviews literature on the impact of the net-zero transition on the labour market and the lessons learned from CGE modelling around the world. It also reviews the few skills analyses that have taken a quantitative approach. Section 4 details the methodology of the labour market model—the gTech—and skills analysis, along with its justification. Section 5 explains the differences and similarities of the three decarbonization scenarios and their assumptions. Section 6 discusses the employment results of the model and skills implications emerging from our analysis. Section 7 provides our conclusions and outlines some key policy recommendations that arise from this analysis. Section 8 identifies areas for future research that could potentially build on this analysis.

BOX 1

How does decarbonization impact the labour market?

The transition to a decarbonized economy is expected to substantially change the labour market. Chateau et al. (2018) identified four main channels through which these changes will occur (and are already occurring):

Changes in production modes and technologies:
Firms shift away from using high-carbon or "dirty" inputs in production toward cleaner technologies and production processes. This changes production costs and transfers jobs between sectors. This transfer is determined not only by the level of activity in that industry, but also by how easily labour can be replaced by other inputs.

Changes in demand patterns:
Demand for commodities with potential negative environmental impacts is replaced by increased demand for low-carbon or "clean" commodities and intermediate products.

Changes in macroeconomic conditions:
Depending on the decarbonization pathway, household incomes change, which changes demand patterns, savings, and labour supply. Other macroeconomic effects include adjustments in public budgets through, for example, carbon tax revenues, which can be recycled to households or which can finance other public expenditures.

Changes in international trade:
Changes in production and prices lead to changes in international trade and trade competitiveness. This can occur through changes in trade balance and real exchange rates induced by changing levels of exports and imports, which also impact domestic labour markets.

SECTION 2:

Impact of a Net-Zero Transition on Labour Markets

Lessons learned from General Equilibrium modelling

Simulations using CGE models vary depending on the assumptions of the scenarios modelled. Results are context-specific and determined by the variables modelled as well as the initial GHG levels (OECD, 2012). However, despite the variability in the results, a wide range of studies indicate that decarbonization has an overall neutral or even positive net effect on employment (Bassi et al., 2010; Cedefop, 2013; OECD, 2012). Indeed, the empirical literature on emissions reduction from a wide range of modelling tools has reached a general agreement that emissions can be drastically reduced without hindering economic growth and job creation (Bataille et al., 2016). However, there is a clear need for policies to mitigate transition costs associated with a net-zero goal in order to fairly distribute costs and benefits.

One of the first comprehensive studies[8] on the transition to a net-zero future, completed in 2008, indicated that such a transition is expected to create some jobs, substitute others, fundamentally transform some, and eliminate several existing ones (Renner et al., 2008). The most dramatic impacts of decarbonization on the labour market are expected to occur in the long term, as the demand for highly skilled labour is spurred by the diffusion, adaptation, and experimentation of new technologies and production processes (Fankhaeser et al., 2008). Several studies advance the argument that, as the world decarbonizes, climate policy has positive effects on employment (Bataille et al., 2016; Fankhaeser et al., 2008; Renner et al., 2008). However, job creation is also a function of subsidies and financing mechanisms (Böhringer et al., 2013).

Since the publication of these studies, a host of models have been developed to analyze and evaluate the impacts of

8 This study was commissioned by the Green Jobs Initiative of the International Labour Organization (ILO), the United Nations Environment Program (UNEP), the International Organization of Employers (IOE), and the International Trade Union Confederation (ITUC) to promote "opportunity, equity and a just transition towards green economy and solutions" (ILO, n.d., para. 1). The Green Jobs Initiative ran between the years of 2009 and 2014.

> *Energy efficiency measures not only create jobs across sectors, but also lead to strong growth in high-skill-level jobs, including those of managers and professionals.*

environmental policies on the labour market.[9] Among the most widely used models for this purpose are CGE models that use a set of economic equations that simulate the economy and the behaviour of participants within that economy. This baseline captures the structure of the economy in a state of equilibrium (i.e., before any change is introduced). After a significant change is introduced, the economy finds a new equilibrium resulting in a new set of prices and different cross-sectoral impacts on allocations of goods and factors.

While a large chunk of CGE modelling has focused on assessing the impact of decarbonization pathways on macroeconomic indicators such as gross domestic product (GDP), relatively few studies have focused on the impacts on the labour market. In Europe, studies have estimated a positive impact of decarbonization on GDP and employment. Kratena (2018), for instance, estimates that scrappage policies[10] for vehicles and domestic electric appliances, along with investments in retrofitting lead to growth in GDP and employment. This impact is more dramatic than that of policies that increase the diffusion of renewables for power generation. Other modelling exercises vary the technology mix to show a positive impact on total employment across the European Union (Cambridge Econometrics, 2013). Energy efficiency measures not only create jobs across sectors but also lead to strong growth in high-skill-level jobs, including those of managers and professionals. This demand comes from growth in jobs in the engineering and manufacturing sectors and is starker in scenarios characterized by high energy efficiency and renewable energy development.

According to some estimates, a low-carbon transition would re-allocate about 1.4% of EU jobs in 2050 (Fragkos & Paroussos, 2017) with overall employment experiencing a net positive impact. The greatest number of jobs is created in the electricity sector, agriculture (driven by biofuel production), and construction (driven by solar photovoltaic systems and retrofitting buildings). In the Spanish context, Rosa Duarte and colleagues modelled three decarbonization scenarios using a CGE model. These

9 Some examples of such models are dynamic input-output models, integrated assessment models, environmental footprint models (EF), life-cycle assessment, impact analysis in environmental extended input-output models, input-output in macroeconometric models, and computable general equilibrium models (CGE). For more information, please refer to *Input-output analysis: Foundations and extensions* (Miller & Blair, 2009) and two special issues of *Economic Systems Research* (2013, vol. 25, issue 1 and 2014, vol. 26, issue 3).

10 Scrappage policies are policies that encourage consumers to reduce the length of their vehicles' or durable household appliances' lifetimes. They do this by offering incentives, such as cash payments, to consumers to turn in—or "scrap"—their old inefficient vehicles and appliances and buy new, more efficient ones.

scenarios included energy improvements produced by existing technologies and those produced by industries and households. The results indicate that these measures not only reduce emissions and increase energy efficiency, but also lead to greater economic growth, particularly when paired with alternative low-carbon emitting technologies. Indeed, increases in consumption and reductions in the long-term unemployment rate are both predicted in scenarios that include improvements in energy efficiency (sometime around 2030 and 2040, respectively) (Duarte et al., 2018).[11]

For the Canadian context, Navius Research Inc. has previously used the gTech model, a dynamic CGE model of the North American economy, to forecast clean energy economic activity to 2030 simulating different energy technologies and policies. This modelling foresees a 3.4% increase of clean energy GDP and increases in clean energy jobs from 398,000 to 559,000 between 2020 and 2030. These increases are led by new jobs related to electric and hybrid vehicles; clean buildings; and transit, wind, and low-carbon machinery. However, emissions are expected to amount to 673 Mt CO_2e in 2030, which was still 161 Mt CO_2e higher than Canada's previous 2030 target of reducing GHG emissions to 30% below 2005 levels under the Paris Agreement (513 Mt CO_2e) (Navius Research Inc., 2019).

As economies decarbonize, changes in the industry composition of jobs will lead to changes in the demand for certain skills.

11 For CGE modelling focused on middle- and low-income countries, see the case for Chile by Nasirov et al., 2020 and for South Africa by Altieri et al., 2016.

An important insight from this analysis is the increasing job polarization in Europe coupled with a shift in the future toward more autonomy, spontaneity, and social and intellectual tasks and away from physical and routine tasks.

However, while CGE models can analyze variation in jobs across sectors, they cannot assess or quantify the demand for skills. To overcome this shortcoming, previous studies have employed a two-pronged approach. They first use CGE modelling to identify the impact of clean technology investments on jobs, depending on the technology mix, labour intensity, ability to domestically produce and export alternate energy, and modelling assumptions. Next, they use local job classifications and databases to identify and analyze skills that are extremely important for the renewable sectors. Shortages of highly skilled workers can intensify competition and undermine the cost-efficiency of a net-zero transition, making it critical to mitigating possible adverse side effects of renewable energy expansion on the labour market in carbon-intensive economies (Fragkos & Paroussos, 2017).

Very few studies have concretely modelled skills demand in a decarbonized future,

owing to the subjective and static nature of skills. A comprehensive study of Europe, however, used a framework to inform labour market projections to 2030 and quantify the demand and supply of skills (Cedefop, 2018). Overall, modest growth in jobs is expected across Europe up to 2030, led by service sector growth, particularly for highly skilled workers including managers, professionals, and associate professionals. Some growth is expected in lower-skill-level jobs like sales, security, cleaning, catering, and caring, but medium-skill-level jobs, especially in the agriculture sector, will suffer. An important insight from this analysis is the increasing job polarization in Europe coupled with a shift in the future toward more autonomy, spontaneity, and social and intellectual tasks and away from physical and routine tasks.

The Brookfield Institute's Forecast of Canadian Occupational Growth uses a new tool to understand how Canada's labour market could evolve up to 2030. Their 2019 study uses this tool to combine foresight research, expert insights, and machine learning to project job growth, identify skills in the labour market, and recommend skills development initiatives. Following an established pattern, social and cognitive skills emerge from this analysis as critical for the future of work. These include fluency of ideas, memorization, instructing, persuasion, and service orientation (Brookfield Institute for Innovation + Entrepreneurship, 2019). Additionally, Brookfield's study uses the Canadian National Occupation Classification (NOC) system and its link with the Occupational Information Network (O*NET)[12] to identify jobs for the future and their associated skills profiles. Importantly, the skills identified as important for the future are similar to those found to be significant in this report.

12 The O*NET is a comprehensive database developed by the United States Department of Labor, Employment and Training Administration. It consists of a comprehensive list of occupations across all sectors and industries and their definitions. For each occupation, it also includes detailed information on its associated attributes, including the skills, abilities, and knowledge and training required to undertake that role.

SECTION 3: Methodology

The analysis presented in this report utilizes a quantitative approach to assess the employment changes and skills requirements in Canada's transition to a net-zero economy. As a first step, we use a dynamic CGE model to simulate different decarbonization pathways to assess job changes in Canada.[13] The second step takes the sectoral job results from each possible decarbonization pathway and connects them with the relevant occupations and skills profiles. This second step helps answer the question: Regardless of which decarbonization pathway Canada ends up pursuing, what are some of the skills that will be most relevant in the future?

Identifying jobs of the future: the gTech model

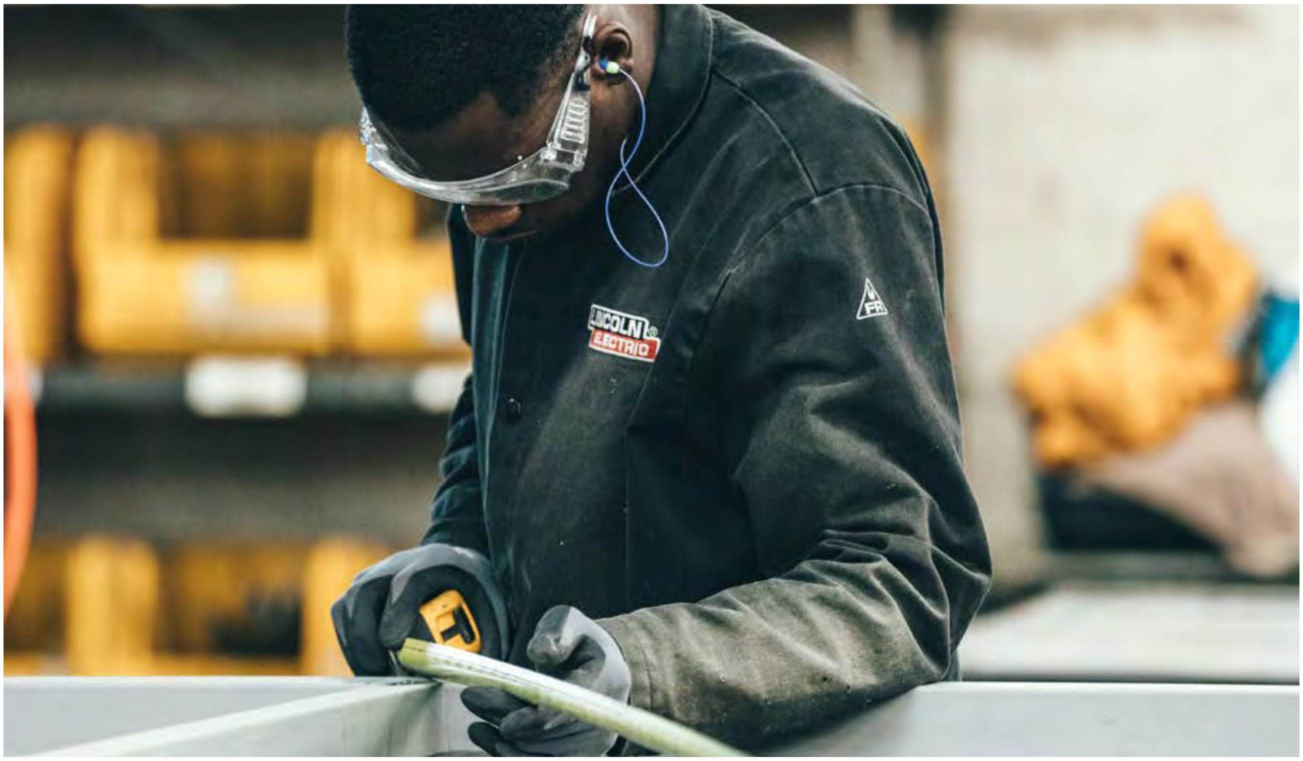
For the first step, our analysis utilizes the gTech model housed within Navius Research Inc. The gTech model is a recursive dynamic CGE model that captures sectoral activity and transactions that occur between households, firms, and governments. It is well-suited to assess the impact of a net-zero emissions future because it represents energy markets and energy-related technologies and combines them with information on consumer behaviour, consumer preferences, and Canadian macroeconomic data (Navius Research Inc., 2021).

The gTech simulates these results by varying GHG reduction policies, technology, energy cost, and future oil price assumptions. Notably, this is done at the national level for Canada and also at the regional level for 11 regions (including territories) in Canada and the United States.[14] To assess the macroeconomic effects of a transition to a net-zero economy, the model is used to quantify labour market outcomes across three decarbonization pathways (these pathways are explained in Section 5).

For labour market outcomes, the gTech is calibrated to labour statistics from Statistics Canada's System of National Accounts. The model simulates labour market outcomes

13 Modelling decarbonization pathways helps identify the cost-effective paths to a net-zero emissions future. In such an approach, the aim is to determine the end goal and then work toward that goal, varying the features of pathways to analyze their differences (Green, 2019).

14 Modelling the United States economy as part of the gTech allows for an explicit simulation of the trade relationship between Canada and the United States based on historical data. Given the importance of this trade relationship to Canada, doing so is critical to accurately model the Canadian economy.



as a function of sectoral activity (i.e., how much each sector grows/shrinks in the decarbonization pathways) and wage rates (i.e., higher wages in one sector will drive employment in that sector). Specifically, we show how many jobs will be created in each sector in 2050, relative to the 2015 baseline numbers for each pathway.[15] Refer to Appendices 1 and 2 for further details about the gTech model.

Linking jobs with their skills profiles

Despite its advantages, the gTech model is unable to assess the impact of different decarbonization pathways on skills requirements. Therefore, the second step of this analysis is to combine the model results with skills profiles. This step, summarized in Table 1, can be divided into four parts:

1. First, the analysis looks at sector-level jobs from the g-Tech model,[16] where sectors are defined using the North American Industry Classification (NAICS) system, and identifies where jobs have been gained and lost. This helps shortlist relevant sectors for further analysis across the three decarbonization pathways.

2. The sectoral-level data is then converted into occupational-level data using the Canadian NOC system. This is done

15 The gTech uses 2015 as the baseline year because the model is calibrated to labour statistics that are consistent with the 2015 System of National Accounts from Statistics Canada. For instance, 2015 employment by industry or NAICS code is mapped onto the sectors in the model. Moreover, 2015 was also the year that the Paris Agreement was reached, making it a meaningful starting point.

16 The modelling analysis and the associated skills analysis was conducted in spring 2021. This is important to note for two reasons: 1) The O*NET is a dynamic database that continues to evolve as new occupational information becomes available; 2) A newer version of the NOC was released by Employment and Social Development Canada and Statistics Canada in fall 2021, which may also alter the results of this analysis.

by retrieving employment data for each NOC occupation employed within each of the 20 NAICS sectors.[17] This comprehensive dataset covers the 2019 Labour Force Survey (LFS) and is retrieved from Statistics Canada's Real-Time Remote Access tool. This dataset provides details on which occupations are employed within each NAICS 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.

3. From the occupation level, the analysis develops a skills profile for each occupation using the O*NET database from the U.S.[18] The O*NET database offers detailed information about the importance and level of usage of 35 skills in different occupations. This database was selected because it provides an objective way to link the NOC to O*NET through a concordance table (sometimes referred to as a crosswalk) developed jointly by the Labour Market Information Council (LMIC), Employment and Social Development Canada (ESDC), and Statistics Canada (LMIC, 2020). Using this crosswalk, the standardized scores for "importance" and "levels" are extracted for each NOC occupation.[19]

4. Then, using the weights of occupations and standardized scores for "importance" and "level"[20] identified in each skills profile, this analysis calculates the weighted average standardized score (WASS) for each of the *p* skills based on the *i* occupations in the relevant sectors. This final step helps determine the top skills requirements within industries and the top skills that will be needed across all decarbonization pathways. The formula for WASS is given by Equation 1.

EQUATION 1

$$WASS^p = \sum_{i=1}^{n} weight\ of\ occupation_i \times standardized\ score_i^p$$

17 The dataset includes employment for each four-digit NOC for each of the NAICS sectors (disaggregated up to the four-digit industry group level). However, the four-digit NAICS industry group level was aggregated at the two-digit sector level in a way that is aligned with the NAICS codes used in the gTech. Since the gTech uses a combination of two-digit, three-digit, and four-digit NAICS codes, these codes were aggregated at the two-digit level to conduct the analysis consistently across sectors.

18 Even though the NOC by Statistics Canada includes skill levels, those levels represent the kind and/or amount of training or education required to enter an occupation. Their main purpose is to distinguish between "skilled" and "non-skilled" occupations, so they are not very detailed. The NOC's four skills levels are: A (university education), B (college education or specialized training), C (secondary school or on-the-job training), and D (on-the-job training).

19 The "importance" and "level" of skills are different. A skill may be equally important for a variety of occupations but the level of that skill needed may differ between occupations. For example, "speaking" is equally important for a lawyer and paralegal. However, the lawyer (who frequently argues cases in court) requires a higher "speaking" skill level than a paralegal.

20 The WASS for the "importance" of skills only is reported here due to the fact that results have been aggregated at the sector level, which tends to neutralize variations across the two categories of scores for individual occupations.

TABLE 1

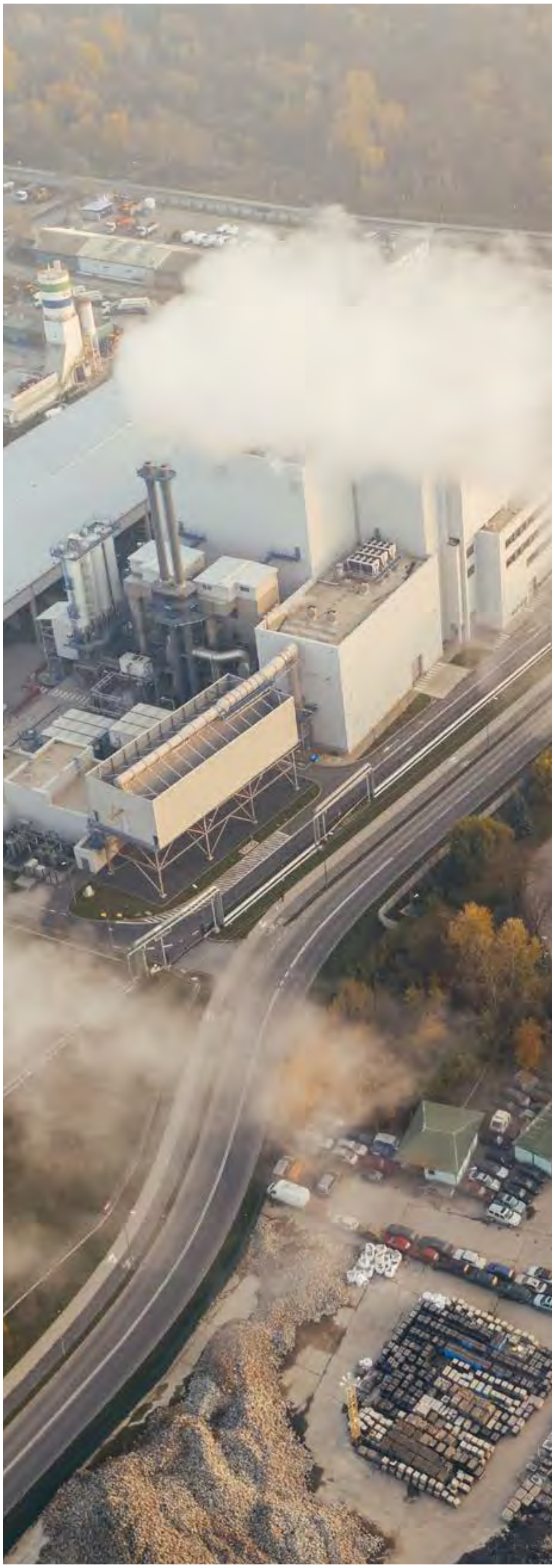
Skills assessment approach

Step	1	2	3	4
Details	From gTech model results, analyze jobs gained/lost in different sectors (classified under NAICS)	From each sector, determine occupations (classified under NOC) where labour force is employed - utilizing LFS Survey data	For each occupation (NOC), extract skills profile using the concordance table between Canadian NOC and U.S. O*NET	Using the weights and standardized scores, calculate weighted average standardized scores for "importance" and "levels" of the skills in different sectors
Outcome	Identify sectors that are most relevant for each decarbonization pathway	Calculate the weights based on the number of people in each occupation compared to the total employment for a specific sector	Extract standardized scores for "importance" of skill and "level" of usage for each occupation	Determine the top skills for relevant sectors in each of the decarbonization pathways

Why this skills analysis approach works

The skills analysis approach outlined above offers a credible way to assess skills needs by linking occupations with their skills profiles and calculating their weighted-average importance scores. The O*NET database has been used in the past by Canadian researchers for skills analysis (e.g., Pollin & Garrett-Peltier, 2009). With the availability of the concordance table, it was possible to link the two datasets and compare Canada's occupations against 35 objective skills and their scores. The approach used in this report is particularly well-suited to analyzing changes across scenarios, as it employs a quantitative method that considers the skills associated with potential decarbonization pathways using 35 unique skills from the O*NET and their weighted importance scores using industry employment data.

It is important to identify that the 35 skills used in this analysis include the skills that a worker would require to undertake an occupation. However, the analysis does not speak to the application or deployment of these skills for a specific occupation in a specific context. For example, a mechanical engineer would possess a similar skillset and qualifications to work at either a wind farm or a solar farm. Beyond basic content skills, these skills would include critical thinking, complex problem solving, operations analysis, judgement and decision making, and systems evaluation. However, the deployment of these skills at



the two farms would be different given the two different contexts. Although analyzing these experience-based skills resulting from deployment of generic skills is also important, focusing on the generic skillset is an essential first step to understanding skills commonalities across occupations. This would support worker transition from one set of jobs to another, making skills transferability an important lever to support worker transition and train new workers entering the labour force. For a more detailed justification of this approach and a comparison of the approach to skills analysis used in this report relative to other studies, please see Appendix 3.

Although analyzing experience-based skills resulting from deployment of generic skills is also important, focusing on the generic skillset is an essential first step to understanding skills commonalities across occupations.

SECTION 4:
Decarbonization Scenarios

This report identifies changes to the jobs and skills landscapes that emerge from a set of plausible futures with the aim of enabling smart skills policies that are resilient across a range of potential decarbonized futures. To this end, three decarbonization pathways, or scenarios, have been identified. All three scenarios describe a different pathway to a net-zero emissions economy by 2050, with carbon intensity the varying factor among the scenarios. Two scenarios assume that net-zero emissions are reached through direct reductions using a mix of technologies, including CO_2 capture and storage, and the third assumes that technology take-up will be responsible for 75% of emissions reductions, with the rest assumed to be offset elsewhere.[21]

The scenarios outlined below account for uncertainty around the pathways by varying the assumptions about the market, policy, and technology conditions that will influence the level of emissions reduction (Table 2 outlines the main characteristics of each scenario, including GHG emissions targets, technology costs, and prices for oil and natural gas). While Scenario 1 (Electrons) is a lower-carbon-intensity future, Scenario 2 (Resources) involves a heavier continued reliance on carbon-intensive activities while achieving net-zero emissions through alternative approaches, such as the use of carbon capture technologies. Scenario 3 (Blended)—in which overall GHG emissions are reduced by 75%, with the remaining 25% accounted for through the purchase of carbon offsets implemented in other jurisdictions—identifies a more blended perspective where emissions mitigation or capture is responsible for less than 100% of overall GHG reductions (see Figure 1).[22] These three scenarios represent three distinct pathways Canada could take to reach net-zero emissions by 2050. The scenarios, summarized in detail in Table 2, were developed to ensure they contained credible estimates of future trends,

21 This distinction means that emissions are only assumed to be directly mitigated by 75% from 2005 levels in Scenario 3, referred to as Blended in our report, as shown in Table 2. However, this report still refers to this outcome as a net-zero scenario, as it explicitly assumes that carbon/GHG offsets will be used to offset the remaining 25% of GHG emissions by 2050, thereby aligning it with a national net-zero emissions target (see Box 4).

22 This 25% of emissions reduction is not part of the analysis, as it is based on an external policy assumption. While some regional protocols exist for carbon offset schemes, the contours for such schemes, particularly those based on compliance, have not yet been sufficiently defined to allow for them to be modelled or included in sophisticated analyses. These mechanisms for international schemes are also as yet undefined by the United Nations Framework Convention on Climate Change (Dion et al., 2021). (For more information about how offsets might work in this scenario, please see Box 4.)

realistic market conditions, and credible climate action.[23]

Having identified three feasible pathways to net-zero, it is important to recall that the objective of this report is not prediction, but rather the conducting of a foresight exercise. These three scenarios are not meant to independently represent the likeliest futures that will come to pass, nor does this analysis seek to rank the scenarios in terms of their desirability or the probability that they will occur. Rather, each scenario represents a feasible decarbonization pathway for Canada. These three scenarios were intentionally created to be credible, yet sufficiently distinct to yield variance in the trajectory of decarbonization between potential futures in order to illustrate the variation in impacts on skills needs across the economy.

Such an analysis is valuable because different pathways to net-zero will have different impacts on the types of jobs that exist in the Canadian economy and, by extension, the skills needed to perform those jobs. Understanding what skills will be needed will be critical to enabling stakeholders to take the necessary steps to ensure that workers have access to the skills training and development infrastructure they will need to meet the skills demands of the future.

Canada's actual trajectory toward net-zero may contain elements of each scenario contained in this report, along with potential pathways that are not included in this modelling. There is a myriad of credible decarbonization pathways for the Canadian economy: a 2021 report by the Canadian Climate Institute (CCI) modelled 62 different net-zero pathways through which Canada could reach net-zero emissions by 2050, representing a broad mix of potential pathways beyond the three included in this report (Dion et al., 2021). However, the choice to limit the scenarios to three distinct ones allows for a more focused identification of the commonalities among the jobs and skills profiles emerging from each scenario.[24] Each scenario is distinguished by variation in three overarching areas of policy and market conditions and assumptions:

> **The costs, availability, and performance of low-carbon technologies:** Within the model, different assumptions are used for both per-unit cost and availability of a suite of clean technologies. This variation allows for a more credible representation of how the availability and cost of exogenous technologies influence uptake rates across Canada.[25] The list of technologies includes, but is not limited to, electrified personal, freight, and public transit vehicles; hydrogen supply and demand

23 While this report is structured around three distinct scenarios, Scenario 1 and Scenario 2 were generated by varying technology cost, availability, and performance assumptions within the model. They can therefore be conceptualized as two distinct results emerging from a sensitivity analysis arising from changes in market conditions and assumptions.

24 Two assumptions were made to guide the trajectory of the three scenarios examined in this report: 1) that internal carbon pricing schemes for residential and industrial emitters are aligned nationally in 2030 and remain aligned into the future; 2) that carbon pricing revenues continue to be recycled directly to households.

25 The gTech assumes that all increased demand for manufacturing takes place domestically and scales it up in response to changes in policy and technological cost profile. This is because of two explicit features of CGE models like gTech, which are discussed in the technical guide to the gTech in Appendices 1 and 2.

technologies; second-generation biofuels produced from woody or grassy materials; new nuclear power technologies; carbon capture and storage (CCS) or carbon capture, utilization and storage (CCUS) technologies including DAC; and active waste heat recovery technologies. In the Electrons scenario, for instance, the cost for some of these technologies (except CCS/CCUS and DAC) is lower relative to the other two scenarios since more stringent climate policies lead to greater investment in developing and scaling such low-carbon technologies, increasing their uptake across the board and driving down their price points.

The decision to limit the scenarios used in the analysis to three distinct ones allows for a more focused identification of the commonalities among the jobs and skills profiles emerging from each scenario

- **The international price of commodities:** Varying the price of oil and natural gas, which is influenced by changes in commodity prices in international markets, is essential to evaluating the level of investment into given technologies at various price points. Although global commodity prices are exogenous, the price of oil determines capital allocation into clean technologies. For example, if the international price of oil falls due to stringent global climate policy, leading to decreased demand for oil, this would reduce the attractiveness for producers to invest in oil and gas production. Investments would instead be directed toward supporting the development of clean technologies, which, aided by policy, would create more jobs in sectors utilizing these technologies. Alternatively, in scenarios in which the international oil price is higher, the potential returns from investment in oil and gas are also higher, which leads to greater job creation as is the case in the Resources scenario. This, in turn, requires greater investment into CCS/CCUS to meet emissions targets.
- **The stringency of climate policies internationally:** The benchmark used to consider the ambition of global climate policy is determined by policy stringency in the United States. Our analysis assumes a similar level of stringency across both U.S. and Canadian climate policies. This means that all three scenarios in this analysis assume that the two countries implement climate policies that are stringent to the same extent. This simplifies the comparison across different domestic scenarios to reach net-zero emissions. Given recent commitments to decarbonize the U.S. economy made by the Biden administration, this assumption seems reasonable (Reuters, 2021).

TABLE 2

Pathways to decarbonization (all prices in CAD, 2015 values)

	Scenario 1: Electrons	Scenario 2: Resources	Scenario 3: Blended
Year	National GHG Emissions Levels		
2030	523 $MtCO_2e$/yr (30% below 2005 levels)		
2040	299–302 $MtCO_2e$/yr (60% below 2005 levels)		374 $MtCO_2e$/yr (50% below 2005 levels)
2050	0–41 $MtCO_2e$/yr (100% below 2005 levels*)		187 $MtCO_2e$/yr (75% below 2005 levels)
	Cost Profiles Across Scenarios		
Lower relative costs for…	- Electrified road transportation - Hydrogen supply and demand technologies - Second-generation biofuels - Range of industrial efficiency and electrification solutions	- CCS/CCUS technologies, including direct air capture	Mid-range values between Scenario 1 and Scenario 2 for a broad array of costs
Higher relative costs for…	- CCS/CCUS technologies, including direct air capture	- Electrified road transportation - Hydrogen supply and demand technologies - Second-generation biofuels - Range of industrial efficiency and electrification solutions	
Oil prices[26]	\$50.9/bbl – \$68.4/bbl	\$32.11/bbl – \$78.14/bbl	\$92.5/bbl – \$93.9/bbl
Natural gas price[27]	\$4.3/mmBTU – \$5.5/mmBT		

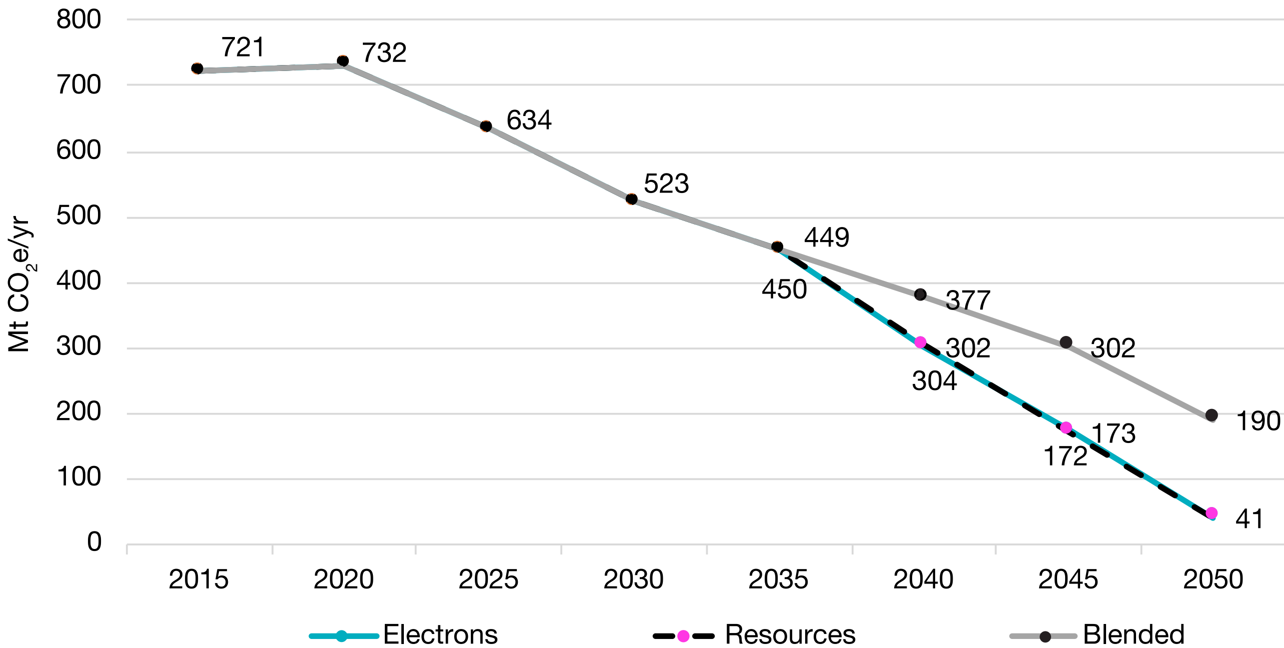
* The final figure of 41 $MtCO_2e$ is assumed to be offset through means not captured in the modelling for this work, meaning the reduction remains aligned with a net-zero future.

26 Oil prices in the report reflect the West Texas Intermediate (WTI) benchmark oil prices only. However, the modelling itself utilizes oil prices for each region and for each type of crude oil. For instance, the light oil price in Alberta is used a proxy for Canadian Light Sweet (CLS), formerly known as Edmonton Par; the Western Canadian Select (WCS) is a weighted price of bitumen and light oil price in Alberta; and the light oil price in the United States is used as a proxy for WTI. The oil prices presented here are converted to Canadian dollars using annual average exchange rates for 2020 (1 USD = 1.3415 CAD) and represent the range from 2030 to 2050.

27 Natural gas prices shown in this table reflect the Henry Hub Natural gas prices from 2030 to 2050. The model also takes into account the prices of Natural Gas at British Columbia’s Station 2 and AECO Natural Gas costs. Costs are converted to Canadian dollars at the 2020 annual average exchange rate (1 USD = 1.3415 CAD).

FIGURE 1

GHG emissions trajectory across decarbonization scenarios to 2050



Source: Drawn from modelling results by Navius Research Inc.

SECTION 5: Analysis of Results

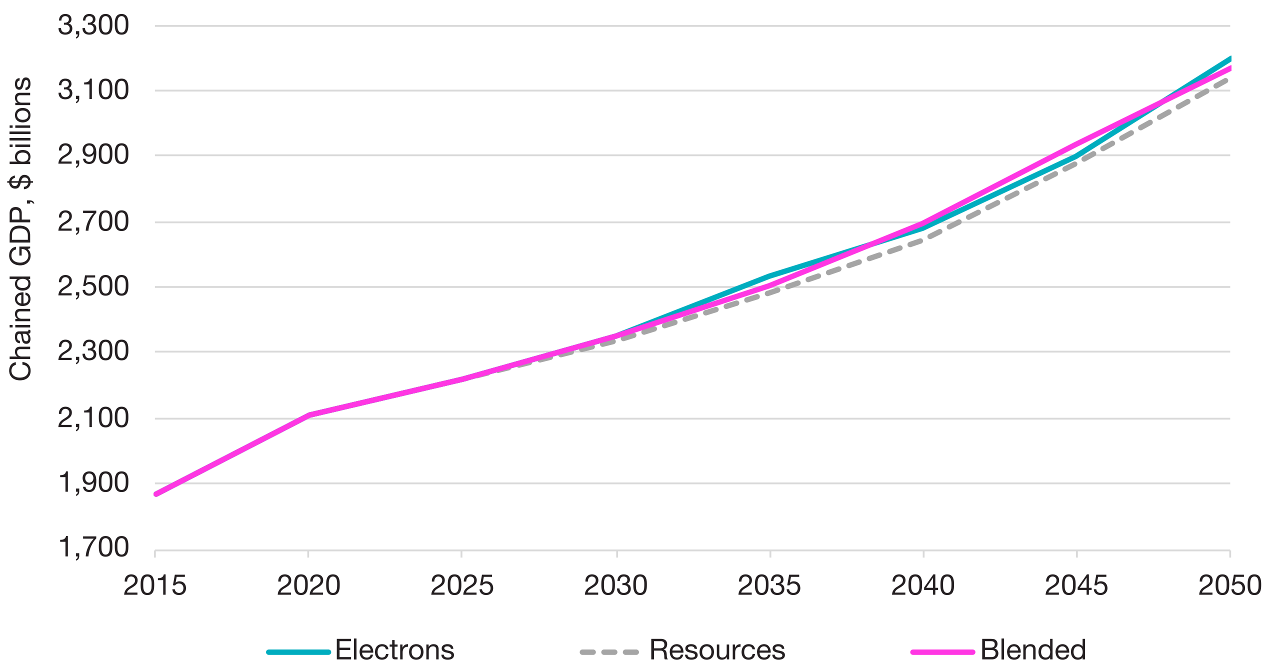
Transitioning to a net-zero future offers several benefits to Canada beyond controlling rising temperatures. Such a future could have a significant impact on the labour market through job creation across a range of sectors. As the uptake of technologies evolves in Canada and fossil fuels are replaced with cleaner fuels, some jobs may be replaced, while others may see an overhaul of their tasks. These evolving roles will require existing and new workers to be armed with the set of skills needed to perform these tasks. This section discusses the impact of the three decarbonization scenarios on economic growth (in the form of GDP) and on jobs across sectors (at national and provincial levels) and identifies how the scenarios might affect the national economy and the four largest provincial economies in Canada.

Impact on economic growth

Modelling exercises using CGE models can be useful to help assess the broader economic impacts of climate policy, including its impact on employment at national and provincial levels. This process manifests as climate policy influencing technology costs, which in turn directly influence the technological allocation across sectors in Canada. These policy choices ultimately shape the kind of investment that flows into various technologies, influencing economic growth and jobs across sectors. Disaggregating the impact of climate policy on jobs across provinces is also useful because the transition will impact the labour market differently in different regions. Provinces like Alberta, where more workers are dependent on the resources sector, will see more jobs replaced across sectors. It is important to note that, in aggregate, these provinces will still experience net positive job creation as sectors expected to be prominent in the transition grow (for example, manufacturing clean technology and carbon capture services).

FIGURE 2

Impact on GDP across decarbonization scenarios



Source: Drawn from modelling results by Navius Research Inc.

Across all three scenarios, Canada's economy continues to grow between 2015 and 2050 (Figure 2).[28] Starting from $1,868 billion in 2015, the GDP (chained or real) grows to $3,197 billion by 2050 in the Electrons scenario (average annual growth rates of 1.40%). In the Resources scenario, the GDP touches $3,142 billion in 2050 (average annual growth rates of 1.34%), and in the Blended scenario, the GDP grows to $3,169 billion by 2050 (average annual growth rate of 1.37%).

Overall, our modelling suggests that long-run economic growth is not highly sensitive to GHG reduction policies (or other technology and cost assumptions). This is largely because the model assumes carbon revenues collected by the government are returned to the economy. It also assumes Canada and the U.S. implement similar "strong" climate policies. Moreover, GDP growth is likely under-estimated across the three scenarios. This is because the model does not account for any costs related to climate change—such as those related to more frequent and intense natural disasters—that are avoided through emissions reductions achieved as part of the scenario's decarbonisation pathway,

28 Energy consumption falls between 1,507 PJ/year and 2,142 PJ/year in 2050 (depending on the scenario), compared to 3,352 PJ/year in 2015.

or the value of other co-benefits resulting from the GHG emissions reductions (see Box 2 on pages 25-26). This particular model also does not take into account economic growth or jobs created from domestic carbon offset schemes.

Another important point to note is the model's inability to capture activity in non-traditional sectors, as they are not yet captured by the NAICS or the System of National Accounts. Recent market analysis by CCI identified emerging opportunities, such as plant proteins and energy storage, that are currently niche but being leveraged by Canadian companies. These emerging opportunities represent significant potential both at home and abroad as demand for such opportunities take off (Samson et al., 2021). One avenue of future research could more deeply examine these opportunities across sectors and how they relate to

One avenue of future research could more deeply examine emerging opportunities across non-traditional sectors and how they relate to different segments of the labour market.

BOX 2

Co-benefits from the transition to a net-zero economy

different segments of the labour market.

The positive potential of the co-benefits that result from climate action has been studied since the 1990s. Beyond more and better jobs, benefits to human health are widely understood as significant co-benefits, as are more efficient resource use, reduced air pollution, technological innovation, and a more equal society (Deng et al., 2017; Pearce D., 1992; Helgenberger et al., 2020).

Improved health is one of the most striking co-benefits, as demonstrated by research into the climate action currently being undertaken in the City of Toronto. This climate action includes building retrofits, the Toronto Green Standard, the low-carbon District Energy System, active transportation systems, public transit, and the introduction of electric vehicles. These actions not only decrease GHGs like carbon dioxide, nitrous oxide, and ozone—as well as other air pollutants like $PM_{2.5}$[29]—they also help prevent respiratory and heart diseases, cancer, and premature deaths. Moreover, these initiatives also help improve mental well-being and reduce disturbance from noise (City of Toronto, 2019). In Toronto, transportation and buildings together accounted for 91% of the city's 2018 GHG emissions (City of Toronto, 2020). Emissions from traffic caused 42% of premature deaths and 55% of hospitalizations due to air pollution in Toronto in 2014, while emissions released from buildings accounted for 28% of premature deaths and 20% of hospitalizations. The main source of emissions from buildings is combustion of natural gas for heating purposes (Gower et al., 2014).

Other important co-benefits of reducing GHG emissions include energy security and technological innovation and its associated spillovers. Energy security can be increased by more localized generation of electricity, which can also create employment opportunities for communities (Newell et al., 2018). Learning-by-doing and economies of scale help make technological innovations—which are initially expensive—cheaper and more useable over time, despite the differences in how these would manifest across sectors. For example, wind power generation and improved insulation of

29 $PM_{2.5}$ are fine inhalable particulate matter or particle pollution, such as dust, smoke, and dirt.

BOX 2 (CONTINUED)

Co-benefits from the transition to a net-zero economy

buildings are two technologies where costs have fallen and mass deployment has become easier in recent years (Jochem & Madlener, 2003). More recently, global demand for electric vehicles and renewable energy—developments significantly encouraged by efforts to reduce GHG emissions—are spurring exciting developments in battery technology that will in turn generate new jobs in the manufacturing and services sectors (IASS, UfU, IET, & CSIR, 2020).

Improved resource efficiency is another important co-benefit. In 2020, 253 cities reported improvements to building energy efficiency through retrofits: 158 of them reported switching to more energy-efficient street lighting, 149 installed renewable energy generation on buildings, 142 were increasing low- to zero-carbon energy generation, and 135 were improving building codes and standards. For all of these cities, improved resource efficiency was a driving co-benefit of these mitigation measures, allowing cities to meet their needs with lower levels of resource use (Carbon Disclosure Project, 2020). Co-benefits often interact in complex ways over an unknown period of time, making them difficult to model effectively using a CGE model. However, these co-benefits are still important, albeit difficult to measure, outcomes of climate action and should be considered when designing investment policies.

Impact on national jobs

As with economic growth, growth in the overall number of jobs in Canada is not highly sensitive to the three scenarios either. The number of jobs continues to grow from 2015 to 2050 in all three scenarios. For instance, there are only 113,000 more jobs in the Electrons scenario (lower-carbon future) than in the Blended scenario (in which the reliance on carbon offset schemes is higher), and there are only 75,000 more jobs in the Electrons scenario compared to the Resources scenario (higher-carbon future) (see Appendix 4 for detailed job results).[30] These job growth numbers are likely to be understated because population growth forecasts are not a direct input in the model. Rather, they are implicitly included in the GDP growth forecast that is used in the gTech, based on the Parliamentary Budget Officer's (PBO) Fiscal Sustainability Report from 2020. Jobs are reported in two different ways in this report—full-time equivalents and total jobs. Total jobs are all jobs irrespective of whether they are full-time or part-time, whereas full-time equivalents are total jobs corrected to full-time equivalents.[31]

Even though the Blended scenario reflects lower job creation compared to the other two scenarios, these estimates are likely to be understated because the employment impact of carbon offset schemes is not captured by the model due to uncertainties around the contours of such schemes.

The relatively low level of variation in the number of jobs created across scenarios is due to the fact that the majority of Canadian employment is in sectors that are neither energy-intensive nor GHG-intensive (e.g., retail, wholesale, professional services, etc.). Thus, these jobs are generally not affected by energy and GHG mitigation policies. Their growth is tied to overall economic growth, which is indirectly affected by population and labour productivity growth. Moreover, while slowdowns in resource-intensive sectors could result in job losses in related service sectors, such as the financial sector, these losses will be overall offset by increases in service jobs needed to support growth in renewables and cleaner fuel sectors.

The divergence in job creation numbers that does exist across the three scenarios, like the divergence in GHG emissions trajectory (Figure 1), is driven by the varying levels of stringency in national GHG emissions reduction targets and the policies enacted to achieve them, such as carbon taxes, all of which create ripple effects across the economy. This divergence in GHG emissions reduction targets across scenarios manifests through changing international oil prices over

30 Likewise, labour productivity of each sector is assumed to be constant in the model. Nevertheless, while the analysis does not explicitly account for population growth forecasts, the impact of these forecasts on employment is not expected to be significantly affected by GHG policy. Appendices 1 and 2 contain details on how jobs are modelled in the gTech as well as limitations of the model.

31 All numbers in the report and the appendices, except for those in Table 5 (and those referring to Table 5; see page 40), are total jobs including both full-time and part-time. This is because of two reasons: 1) the model allows the total job numbers to be reported on a sector-by-sector aggregated basis; and 2) total jobs are more accurately reflective of jobs in an economy because, in practice, a certain chunk of jobs tend to be part-time. Table 5 uses full-time equivalents because the model allows this format of jobs to be disaggregated into individual four- or five-digit NAICS sector codes, which is useful when analyzing the clean-energy sectors in detail.

In 2019, manufacturing jobs made up over 9.0% of total jobs in the Canadian economy, construction jobs made up 8.0%, and jobs in the transportation sector made up 4.2%.

the years.[32] Hence, job creation is higher in the Electrons scenario when oil prices fall, whereas it is lower in the Resources scenario when oil prices remain strong. This is because in the Electrons scenario, lower oil prices divert the incentive to invest in the oil sector to other sectors, leading to a shift in economic activity toward other sectors. These other sectors have lower technological cost assumptions, making scaling up more feasible and leading to higher job creation by the time the net-zero transition is achieved in 2050.

In the Resources scenario, on the other hand, relatively higher oil prices lead to strong investment and lower job losses in the oil and gas sectors and substantially more jobs being created in sectors involved in CCS/CCUS. These jobs are not as fungible and do not translate into a substitution in other sectors due to higher technological cost assumptions in these sectors. This results in a slowdown in job creation during this period. The Blended scenario shows the "middle ground" between the two scenarios. Ultimately, the economy undertakes a structural transformation and aggregate jobs converge for all three scenarios in 2050.

While sectoral jobs vary across the three scenarios, this report concentrates on certain sectors that are the most relevant to discussions of decarbonization.[33] Therefore, the focus is on job changes in 2050, relative to 2015, in the manufacturing, transportation, construction, low-GHG energy, CCS/CCUS sectors, and fossil fuel or resources sectors (Figures 3 and 4).

In 2019, manufacturing jobs made up over 9.0% of total jobs in the Canadian economy, construction jobs made up 8.0%, and jobs in the transportation sector made up 4.2% (Statistics Canada, 2019). Clean energy or low-GHG energy sectors, CCUS and DAC sectors, and associated jobs are not directly captured by the NAICS codes or the Labour Force Survey at present. However, the Environmental and Clean Technology Products Economic Account (ECTPEA) measures the economic contribution of environmental and clean technology products including the number of jobs. In 2019, for instance, almost 341,000 jobs were associated with environmental and clean technology activity, making up 1.8% of all jobs in Canada. These jobs were driven by electric power generation, transmission, and distribution; engineering construction; and professional, scientific, and technical services industries. Since these jobs overlap several existing NAICS industries, these numbers might not be directly comparable

32 These oil price assumptions are made to keep each decarbonization pathways distinct from each other and highlight their sectoral implications.

33 For a detailed look at changing job numbers, refer to the tables in Appendices 4 and 5.

with the NAICS industries represented in the LFS. On the other hand, jobs in the fossil fuel sectors and the mining, quarrying, and oil and gas extraction sectors accounted for only 1.4% of total jobs in Canada in 2019.

Broadly, fossil fuel sectors experience decelerated job growth or job declines in 2050, relative to 2015, across the three scenarios. This is more pronounced in the Electrons scenario and less pronounced in the Blended scenario. The largest job gains in 2050 in all scenarios are in the manufacturing, construction, and transportation sectors. Emerging sectors such as CCS/CCUS and low-GHG energy also see job gains in 2050 in all scenarios. This is especially the case in the Resources scenario, where higher fossil fuel consumption is supplemented by carbon storage and DAC to reach net-zero emissions.[34]

The largest job gains in 2050 in all scenarios are in the manufacturing, construction, and transportation sectors. Emerging sectors such as CCS/CCUS and low-GHG energy also see job gains in 2050 in all scenarios.

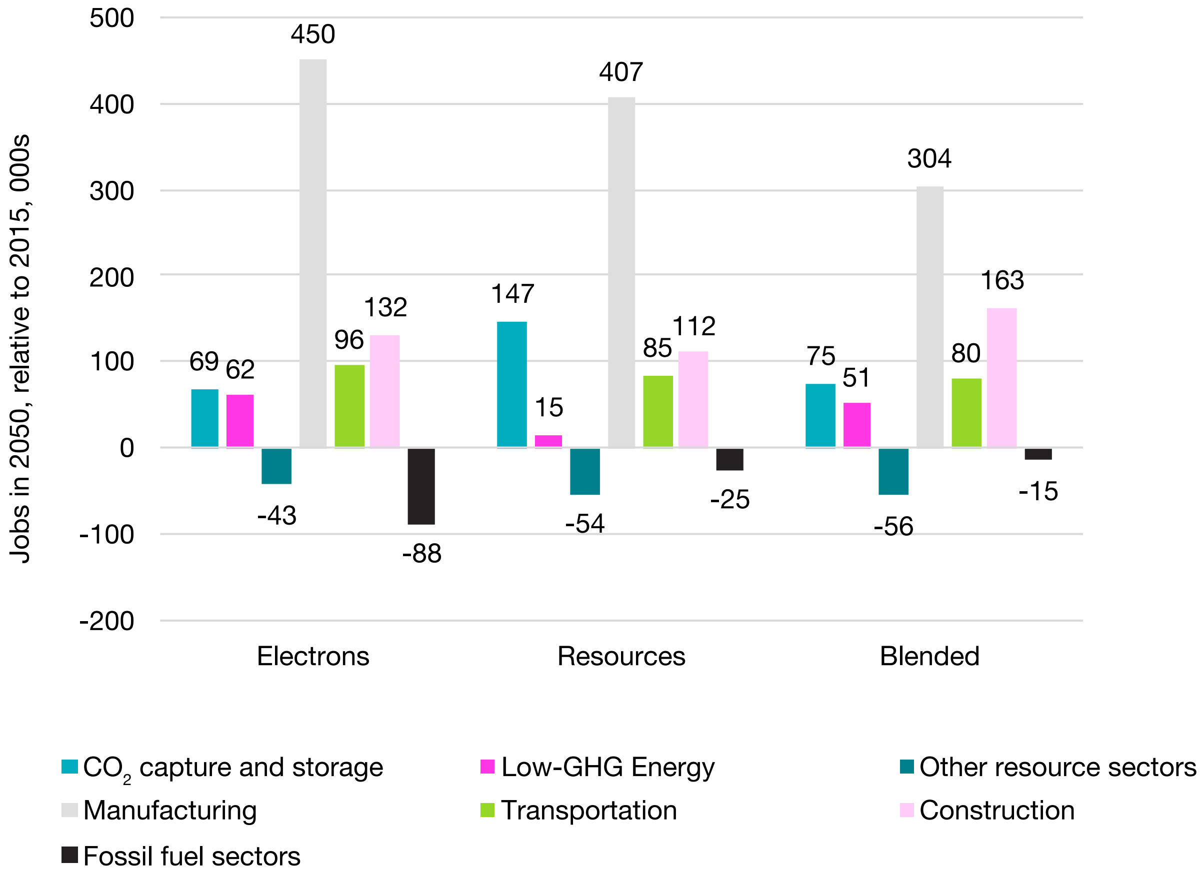
These changes can be explained by the structural transformation created by GHG reduction policies, technology costs, and different long-run oil price assumptions. Due to these changes, employment in the traditional energy sectors (e.g., oil and gas, mining) are substituted with additional employment in emerging energy sectors (e.g., biofuel and hydrogen) or sectors related to energy efficiency (e.g., low-GHG electricity) and management of GHG emissions (e.g., DAC). Regardless of the scenario, the GHG reduction policies, technology, and energy cost changes create higher demand for manufacturing, construction, and transportation in 2050. The increased demand drives output in these sectors, which in turn leads to job gains.[35]

34 The CCS/CCUS sector includes DAC, which is a technology that uses chemical reactions to capture carbon dioxide (CO_2) from the atmosphere (Lebling et al., 2021). In Canada, Carbon Engineering is running a DAC pilot plant in British Columbia. As emerging technology, CCS/CCUS (including DAC) is not recognized as a separate sector in the NAICS. However, it is expected to play a significant role in a net-zero emissions future.

35 This finding for 2050, relative to 2015, is consistent with the findings of Moffatt (2019), where the gTech was used to analyze the effect of stringent GHG policies on the construction sector.

FIGURE 3

National-level impact on jobs in 2050 in three scenarios (000s)

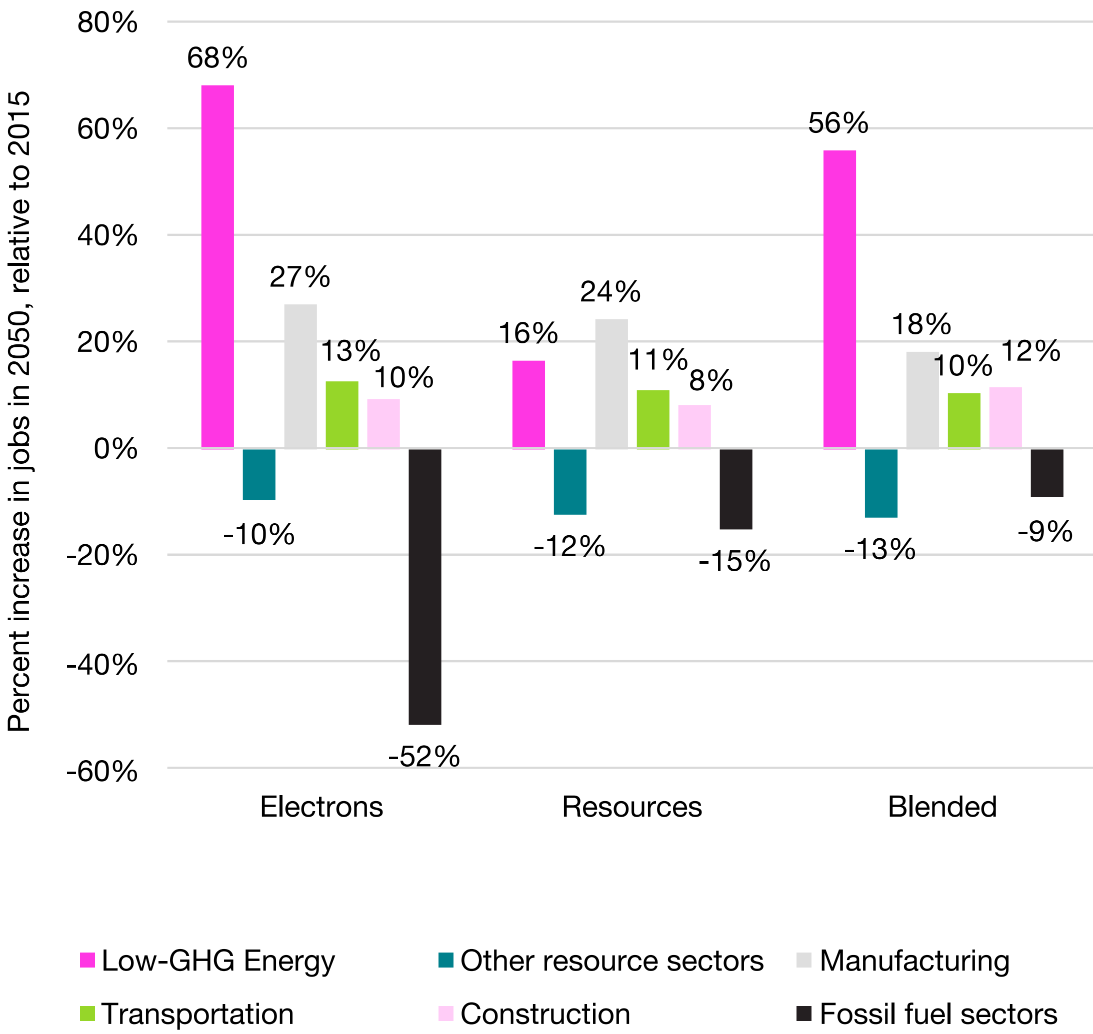


Note: Job gains in the manufacturing sector are driven by computer and electronics, food, and machinery, as these sub-sectors make up the bulk of the jobs. Jobs gains in the low-GHG energy sector include those related to energy generation, distribution, biofuel production, and hydrogen production. The Other Resource sector includes agriculture, mining, and forestry, while CO_2 Capture and Storage refers to DAC.

Source: Drawn from modelling results by Navius Research Inc.

FIGURE 4

National-level impact on jobs in 2050 in three scenarios (percent)



Note: The graph does not include percent growth in jobs in the DAC category because jobs in this area are non-existent in 2015, and grow to 69,000 in Electrons, 147,000 in Resources, and 75,000 in Blended (total jobs, not in full-time equivalent terms).

Source: Drawn from modelling results by Navius Research Inc.

Impact on jobs across provinces

Across provinces, there are significant variations in job creation estimates depending on their pre-existing labour market concentrations. Analyzing these variations is important for assessing which sectors in each province will be impacted more than others in each of the three pathways to a net-zero future. Insights from such an analysis may be useful in guiding provincial-level efforts to prepare their respective workforces to transition from sectors expected to lose jobs to sectors expected to gain jobs. This section focuses on the four provinces with the largest labour markets in Canada, namely, Ontario, Alberta, British Columbia, and Quebec. These four provinces make up almost 90% of total jobs in the country and exhibit significant variations across scenarios that hinge on their pre-existing sectoral concentrations.

Similar to job estimates at the national level, the largest net job gains at the provincial level in 2050, relative to 2015, are found in the manufacturing and construction sectors in all scenarios (Figure 5). Together, these two sectors could make up about 15 to 18% of all jobs across the four provinces (Table 3). However, these gains are more prominent in Ontario, Alberta, and British Columbia. Transportation jobs—making up between 3 and 5% of total jobs—also grow in all scenarios, but more so in Ontario and British Columbia. Ontario, in particular, witnesses job increases in sectors that traditionally provide permanent, full-time jobs with greater benefits than the provincial average (Thirgood et al., 2017).

The largest net job gains at the provincial level in 2050, relative to 2015, are found in the manufacturing and construction sectors in all scenarios.

This is supported by previous modelling analyses for Ontario (Thirgood et al., 2017) that suggest that, even in an accelerated policy ambition scenario in which Ontario's carbon price trajectory aligns with the social cost of carbon, jobs in sectors expected to evolve and grow offer greater stability and financial benefits than jobs in other sectors. The scenario modelled by Thirgood and colleagues is less ambitious than a case that is consistent with the Paris Agreement and hence implies an absence of significant automation or deep decarbonization efforts. This report, on the other hand, offers a modelling scenario consistent with Canada's commitments under the Paris Agreement, with more ambitious decarbonization efforts, suggesting that the jobs expected to be created as a result of these efforts would be full-time and permanent and would offer greater benefits in general.[36]

36 One of the limitations of the gTech model is that it explicitly assumes constant labour productivity over time. Hence, it does not take into other factors, such as automation of jobs over time. Therefore, if the future is characterized by high rates of automation, employment gains in these sectors (and future green jobs) might be skewed more toward highly skilled workers.

Conversely, we see less job growth in oil and gas, fossil fuel-based power generation, and mining in 2050 in all three scenarios. This is especially the case for the oil and gas extraction sector in Alberta, where resource-intensive sectors make up over 5% of total jobs in the province. However, some of these job losses in Alberta are balanced by gains in the emerging DAC sector, particularly in the Resources scenario (which relies more on DAC to offset CO_2 emissions). Fewer jobs in the resources sectors are expected, as some oil and gas assets might become stranded (i.e., they are never exploited because changing economic conditions make doing so unprofitable) in one or more of the potential decarbonization pathways. Job creation is expected in provinces that can quickly leverage renewable energy and low-carbon technology (Green, 2019). Nevertheless, opportunities exist for other provinces as well. For instance, the case study of Alberta presented below (see Box 3 on pages 47-48) describes how a decarbonized future can be based on resilient job growth given the right project investments and transition support.

TABLE 3

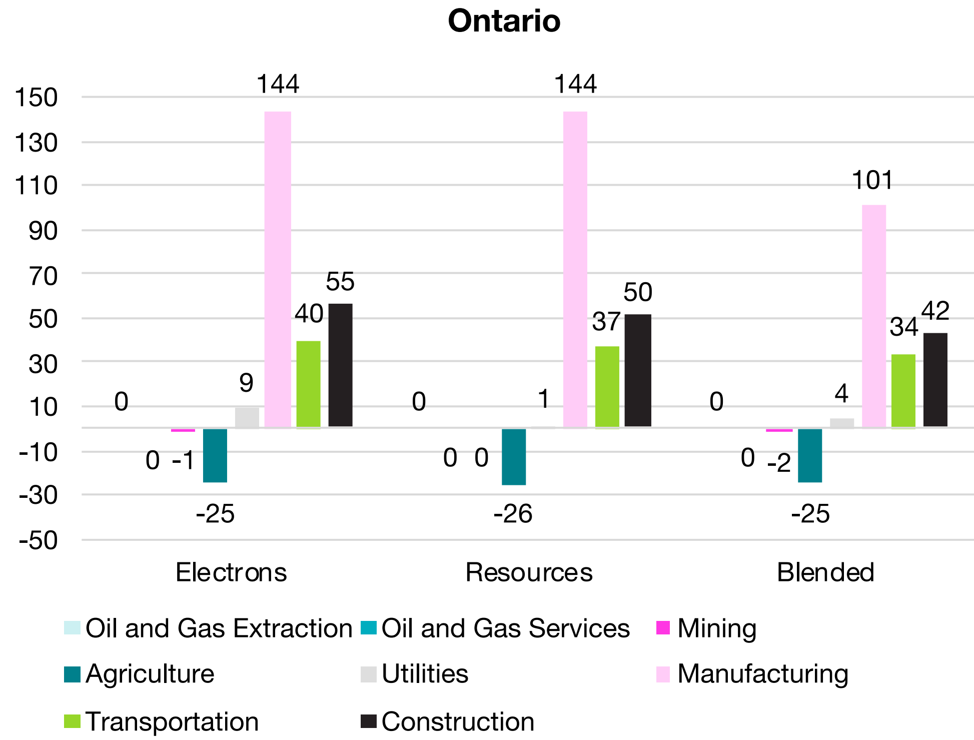
Average employment share of sectors in four provinces in 2015 and 2050 as reflected in the gTech

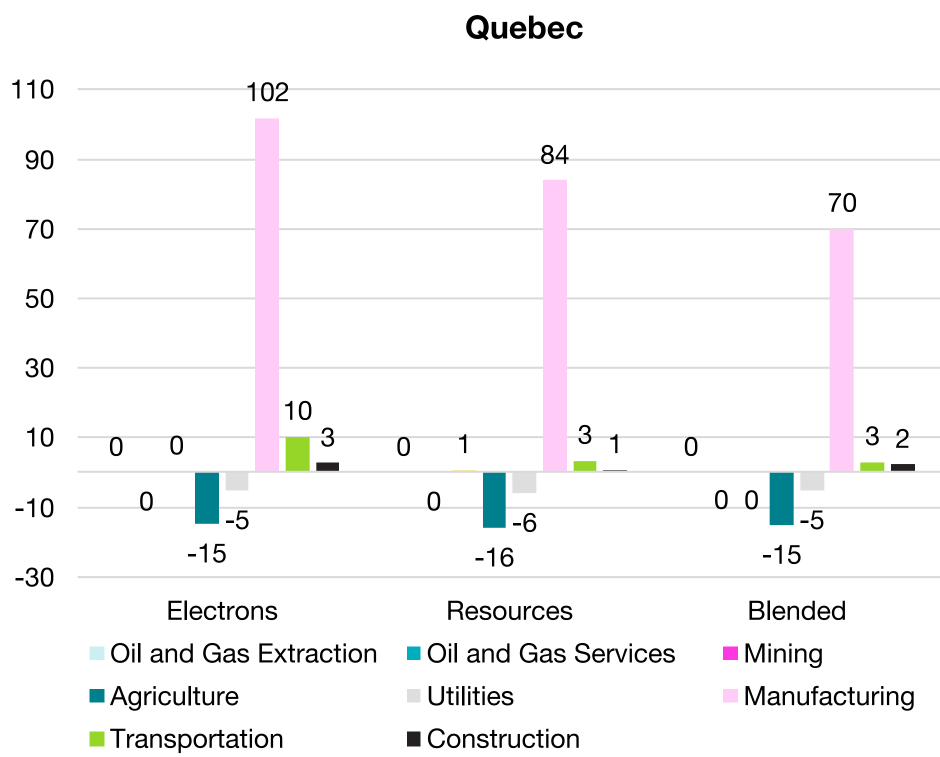
	Ontario		Quebec		Alberta		British Columbia	
Sector	2015	2050	2015	2050	2015	2050	2015	2050
Resources	1.6%	1.1%	2.3%	1.8%	6.9%	4.1%	3.0%	2.6%
Utilities	0.6%	0.6%	0.7%	0.5%	0.1%	0.3%	0.5%	0.5%
Manufacturing	10.9%	11.2%	10.9%	12.1%	6.8%	7.5%	6.3%	7.0%
Transportation	4.5%	4.4%	3.9%	3.8%	3.8%	3.2%	4.9%	4.6%
Construction	6.8%	6.5%	6.2%	5.9%	11.9%	9.6%	8.3%	8.0%
Services	75.5%	76.2%	76.0%	75.9%	70.6%	73.5%	77.0%	77.2%
Direct Air Capture	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%	0.0%	0.2%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

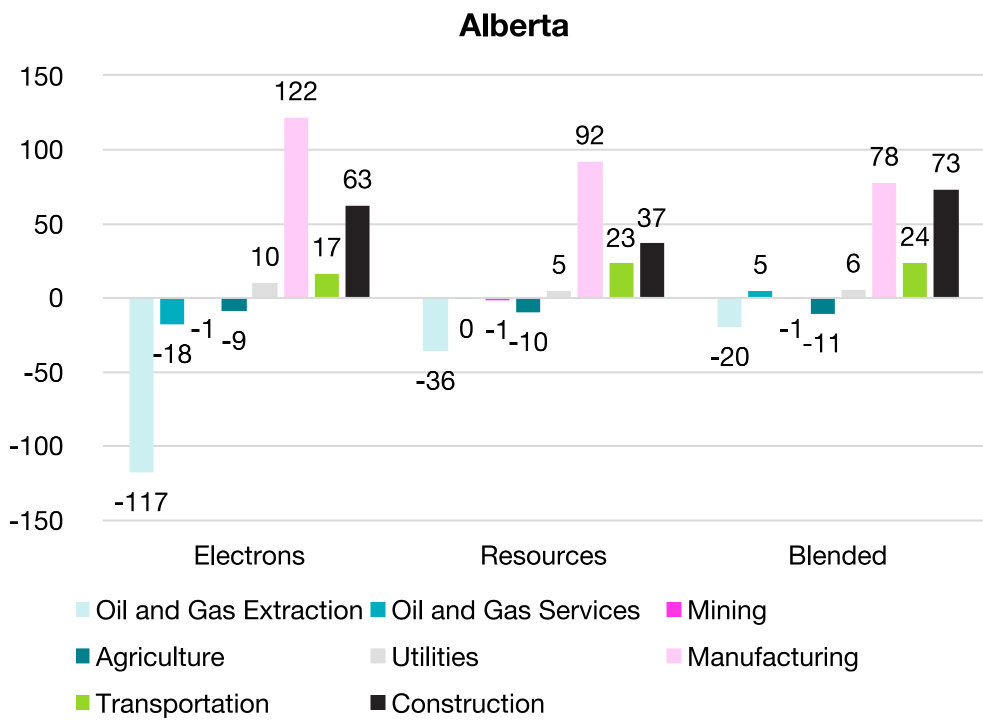
Note: These numbers reflect the average employment shares of the three scenarios in the gTech model in 2015 and 2050. Since the baseline employment numbers for 2015 are drawn from the System of National Accounts, these shares are comparable to data drawn from other official sources, including the LFS.

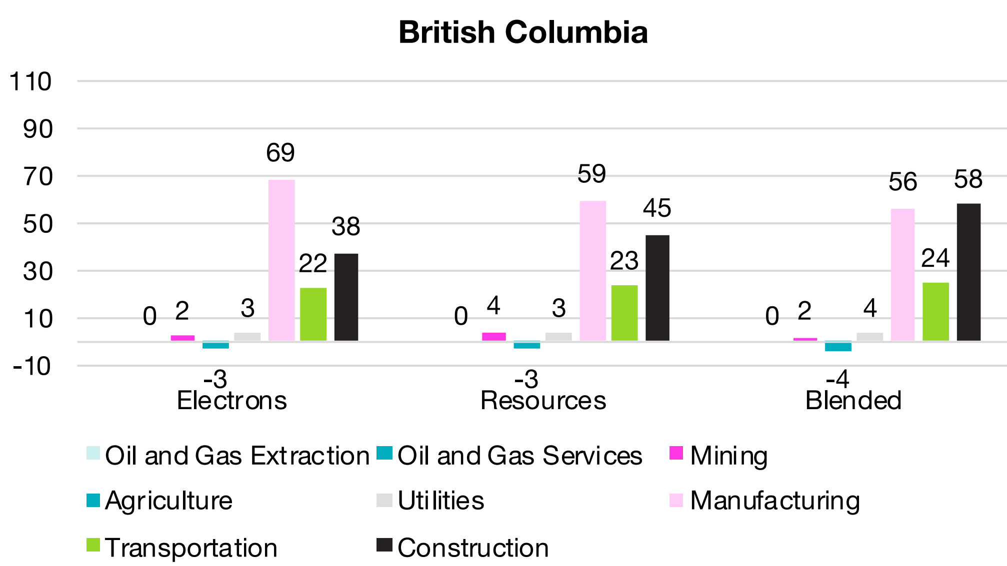
FIGURE 5

Impact on jobs in 2050, relative to 2015, in select provinces in three scenarios (000s)






Alberta
150
100
50
0
-50
-100
-150
-117
-18
-1
-9
10
122
17
63
-36
0
-1
-10
5
92
23
37
-20
5
-1
-11
6
78
24
73
Electrons
Resources
Blended
Oil and Gas Extraction
Oil and Gas Services
Mining
Agriculture
Utilities
Manufacturing
Transportation
Construction


British Columbia
110
90
70
50
30
10
-10
0
2
-3
3
69
22
38
0
4
-3
3
59
23
45
0
2
-4
4
56
24
58
Electrons
Resources
Blended
Oil and Gas Extraction
Oil and Gas Services
Mining
Agriculture
Utilities
Manufacturing
Transportation
Construction

SECTION 6:
Skills in a Decarbonized Economy

As discussed in the preceding section, more stringent GHG reduction policies, lower clean technology costs, and lower long-run oil prices combine to create structural transformations in the economy across all three scenarios investigated in this analysis. These changes lead to significant redistribution of jobs from the traditional energy sectors to emerging energy sectors and sectors related to energy efficiency and management of GHG emissions, as well as the creation of new jobs in these and related sectors. Regardless of the scenario, GHG reduction policies, new technologies, and energy cost changes create higher demand for manufacturing, construction, and transportation in 2050 than would otherwise be the case. The increased demand drives output in these sectors, which in turn leads to job gains. While the gTech modelling gives estimates of these job gains across sectors and provinces for each of the three decarbonization scenarios, the model is not equipped to identify the skills requirements of these jobs. To answer the question of what kinds of skills will gain relative importance in the new economic landscape, the second part of our analysis focuses on connecting the results of the model with occupational and skills datasets.

In this section, we provide an overview of the approach used to conduct the skills analysis and the databases utilized. We then give a summary of the results of this skills analysis and identify a set of skills we see emerging as most relevant for the jobs and sectors modelled earlier. Finally, we close the section with a focused examination of the impact on the clean energy, construction, and manufacturing sectors—three sectors that employ a wide range of occupations and that we see as likely to experience significant job growth—including a discussion of the skills deemed critical to performing some of the occupations in these sectors that will be central in Canada's transition to a net-zero economy.

As discussed in Section 4 on Methodology, the 35 skills from the O*NET used in this analysis focus on the required skills to perform tasks rather than the application or deployment of these skills for a specific occupation in a specific context. For example, a mechanical engineer would possess a similar skillset and qualifications to work at either a wind farm or a solar farm, but the deployment of these skills at the two farms would be different in the two different contexts. While analyzing the experience-based skills resulting from deployment of generic skills is also important, focusing on the generic skillset is an essential first step in understanding skills commonalities across occupations to support worker transition from one set of jobs to another.

Overview of the skills analysis

To understand the skills gaining in importance across the three decarbonization pathways, we constructed a comprehensive dataset linking the Canadian industry and occupational codes with their associated skills profiles. This dataset responds to labour market information specifically related to skills, their associated National Occupation Codes (NOCs), and industry data. This dataset allows us to view the relative importance of each skill quantitatively. This is possible because one of the features of the O*NET database is that it assigns 35 skills quantitative scores for their "importance" and "level."

The measures of "importance" and "level" both indicate the value of a skill to an occupation. "Importance" refers to the relative value between occupations, and "level" refers to the measure of competency required to be effective within a given occupation. Some skills may be equally important for a variety of occupations, but the level of that skill needed may be different in different occupations. For example, "speaking" is equally important for a lawyer and paralegal. However, the lawyer (who frequently argues cases in court) requires a higher "level" of "speaking" skills than a paralegal.[37] Using this information about the various scores of skills, we calculated the weighted-average score for each skill in the O*NET per its importance and level for each occupation, which was weighted according to the number of workers employed in each of those occupations across Canadian NAICS sectors and industries.[38]

37 A more detailed explanation on the importance and level of skills covered in the O*NET database can be found online at: https://www.onetonline.org/help/online/scales

38 While we calculated the weighted-average scores for both importance and level of each skill and each occupation, these results were fairly comparable and hence, for the sake of brevity, we have presented and focused the discussion on the weighted-average importance scores for the skills.

Because the O*NET database is an important building block in the skills analysis, a useful starting point for understanding how we built this dataset is to review the O*NET database itself. Developed by the U.S. Bureau of Labor Statistics (BLS), 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. For this analysis, we limited our focus to the 35 skills identified within the database as classified broadly within basic and cross-functional skills. Basic skills, which include both content and process skills, enable workers to develop capacities that further allow for learning and acquisition of knowledge. These include active listening, reading, critical thinking, and monitoring. Cross-functional skills allow workers to undertake activities across tasks, including coordination, problem solving, operations monitoring, decision making, and management. (For a detailed overview of the classification of 35 skills, including high-level descriptions of each skill, please see Appendix 7.)

Due to their fundamental nature, basic content skills[39] have the highest importance scores across jobs and sectors. They have been excluded from the analysis here because they offer little insight into skills demand beyond identifying that reading and writing will be in demand for all positions. While these findings potentially support policies to bolster these basic skills, they are not useful for identifying novel demands that can inform more targeted and specialized skills training programs or policies. However, basic process skills, such as critical thinking and monitoring, are included in this analysis.

Before analyzing skills scores across scenarios, it is useful to review the highest-ranked weighted-average importance scores for skills across sectors using 2019 labour market data (see Table 4). Basic process skills, like those mentioned above, and cross-functional skills, like complex problem solving and judgement and decision-making, score the highest across all sectors. This corroborates the findings of recent studies of skills that conclude that non-technical skills, including core cognitive and social skills, have higher scores than core technical skills (Brookfield Institute for Innovation + Entrepreneurship, 2019). Even in sectors where technical skills are necessary, like manufacturing and transportation, the importance scores of skills like critical thinking and monitoring is higher than those of technical skills. Critically, this does not render technical skills inconsequential, but it does underscore the importance of the broad-based skills profiles needed for a majority of jobs in a decarbonized future. One of the main findings of a 2019 report by the Canada Green Building Council is that technical skills alone will not be sufficient for low-carbon buildings. A combination of technical and social skills will be needed by workers to deliver energy-efficient and high-performing low-carbon buildings (Canada Green Building Council, 2019).

39 Basic content skills include reading comprehension, active listening, writing, speaking, mathematics, and science.

TABLE 4

Summary of weighted-average skills importance scores by sector

Sector	Employment Share (2019)	Critical Thinking	Active Learning	Monitoring	Social Perceptiveness
Agriculture	2.1%	57.31	43.98	55.21	47.50
Oil & Gas Extraction and Services	1.4%	56.02	44.41	51.16	43.98
Utilities	0.7%	57.98	47.10	52.45	45.74
Construction	8.0%	50.35	41.14	47.64	41.80
Manufacturing	9.1%	54.50	42.24	52.15	46.29
Transportation	5.3%	48.04	37.96	45.96	42.51

Sector	Coordination	Problem Solving	Operations Monitoring	Operation & Control	Decision Making	Time Management
Agriculture	51.51	47.19	49.27	47.09	52.32	49.39
Oil & Gas Extraction and Services	47.66	48.27	45.49	40.13	48.97	45.63
Utilities	47.63	50.85	41.63	32.05	50.57	48.48
Construction	47.67	44.17	41.23	37.09	46.07	46.05
Manufacturing	47.91	46.84	44.86	37.93	48.29	48.14
Transportation	43.74	41.89	43.53	41.56	43.43	45.75

Note: Sectors included in this analysis have been selected based on the gTech modelling results. Jobs in these sectors are expected to experience the greatest impact during the transition to a green economy. These sectors make up about a quarter of Canada's employment, suggesting that the majority of jobs in Canada are not sensitive to emissions reduction policies. Employment shares are from the 2019 LFS, and the skills score range is 0–100.

Common skills in sectors in all three decarbonization scenarios

To identify the skills that are common across all three scenarios, it is important to look at the sectors for which the model calculates the greatest job gains in 2050. The analysis of skills focuses on traditional energy sectors (e.g., oil and gas) where the number of jobs is expected to fall and emerging energy sectors (e.g., energy efficiency and DAC) where the number of jobs is expected to rise. Table 5 provides the industries and sectors that show the greatest net job creation in 2050 along with their top ranking weighted-average skills scores across scenarios. For the most part, the sectors with the highest net gains in jobs are the same in the Electrons, Resources, and Blended scenarios (highlighted in purple in Table 5), even though the magnitude of the gains differs among the three scenarios. The common skills profiles for these sectors have been presented together below.

TABLE 5

Top skills common for sectors experiencing jobs gains across decarbonized futures

Sector Name	Job Changes in 2050, Relative to 2015 (000s) *			Basic Process			Social Skills			PS	Technical Skills					Systems Skills			Man-age-ment
	SC1	SC2	SC3	CT	AL	MO	SP	CO	SO		PO	OM	OC	RE	QC	JD	SA	SE	TM
Electricity Generation & Distribution	+52	+33	+41	60	49	53	47	49	44	53	17	42	31	28	39	52	43	41	50
Construction	+151	+128	+188	50	41	48	42	48	37	44	5	41	37	28	38	46	33	32	46
Manufacturing	+468	+399	+329	54	42	52	46	46	37	47	12	45	38	26	42	48	36	34	48
Food	+64	+66	+54	52	39	51	46	47	37	43	9	44	38	24	38	45	33	30	45
Textile, Clothing, & Leather	+37	+34	+26	52	38	53	45	46	33	46	8	41	35	19	39	48	32	31	48
Wood Products	+44	+38	+37	45	34	42	37	39	30	38	8	37	33	22	35	40	28	27	40
Hydrogen	+15	+5	+10	62	51	58	51	53	43	56	17	46	39	23	40	57	45	45	52
Biofuels	+27	+4	+31	62	51	58	51	53	43	56	17	46	39	23	40	57	45	45	52
Fabricated Metals	+40	+34	+32	55	42	54	47	49	36	47	11	48	42	29	42	48	35	33	49
Machinery	+89	+59	+45	58	45	54	49	50	39	51	46	38	28	44	51	40	38	51	23
Computers & Electronics	+67	+50	+39	60	48	53	48	50	41	53	21	43	31	27	44	53	44	41	50
Transport Equipment	+20	+26	+2	55	44	52	45	48	37	48	12	48	39	31	47	49	37	37	48
Transportation	+106	+98	+95	52	43	51	46	49	43	47	6	55	55	36	36	48	29	31	52

Note: The job numbers for each scenario represent absolute changes in 2050 relative to 2015, and the unit is thousands. The skills scores are weighted-average scores for these sectors (explained in Section 4) and the range is 0–100, with a higher score reflecting greater importance. Due to the size of the table, the headers are abbreviated per the legend below. This table includes the sub-sectors within each sector that gain jobs from 2015 to 2050. Certain sub-sectors within each sector also lose jobs; these are shown in the table in Appendix 6.

*The job changes reported in this table are in full-time equivalents, that is, total jobs corrected to full-time equivalents (i.e., accounting for sectors where there are many part-time workers). In the rest of the report, we report numbers for total jobs, regardless of whether they are full-time or part-time. The full-time equivalents category of jobs in the model allows us to disaggregate the manufacturing sector to include sub-sectors of interest, including transport equipment, machinery, and computers and electronics, which the total jobs category does not allow.

Legend:

SC1: Scenario 1 (Electrons); SC2: Scenario 2 (Resources); SC3: Scenario 3 (Blended).

CT: Critical thinking; AL: Active learning; MO: Monitoring; SP: Social perceptiveness; CO: Coordination; SO: Service orientation; PS: Complex problem solving; PO: Programming; OM: Operations monitoring; OC: Operations & control; RE: Repairing; QC: Quality control; JD: Judgement & decision making; SA: Systems analysis; SE: Systems evaluation; TM: Time management.

Energy

ELECTRICITY

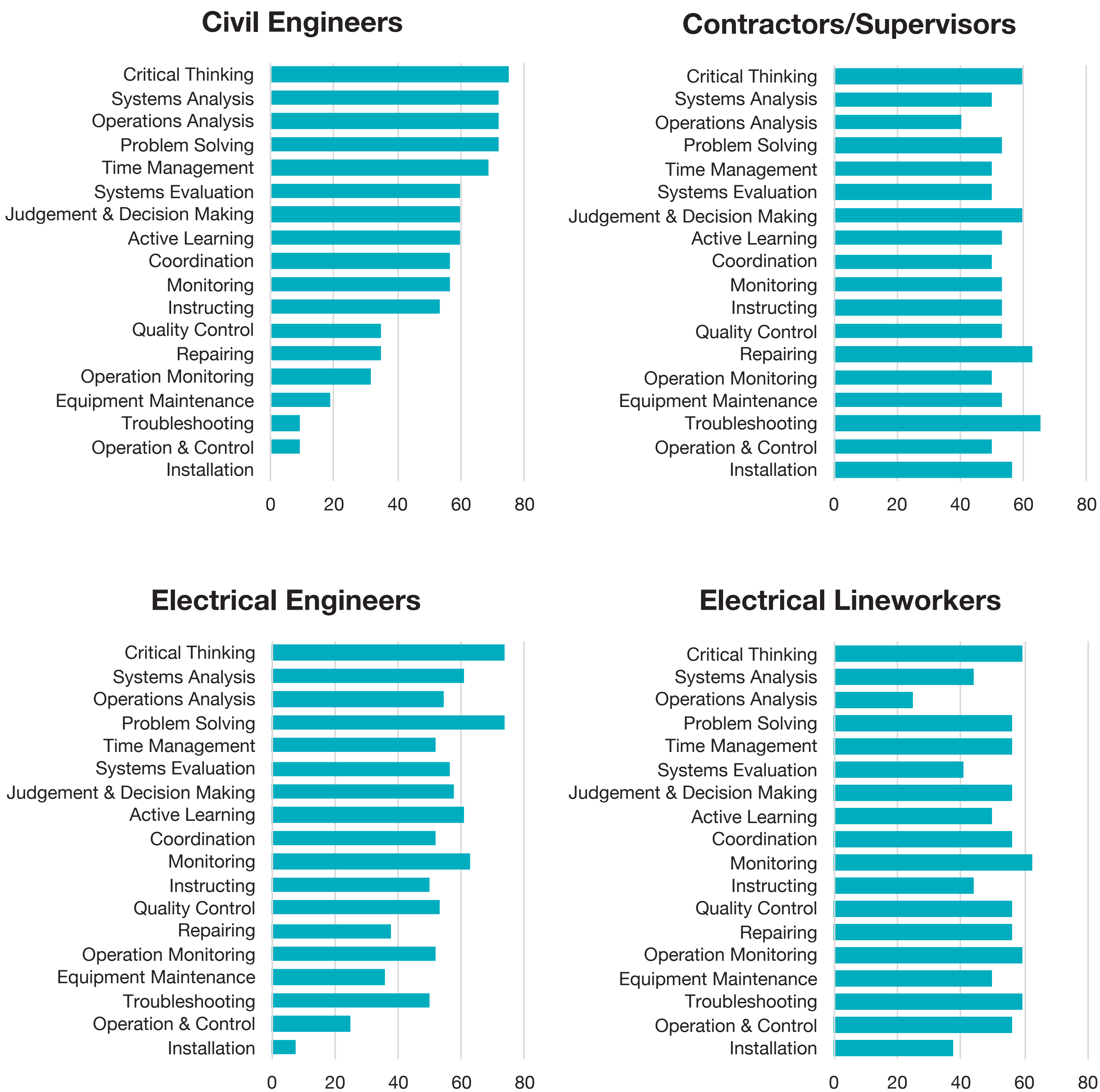
As Canada embarks on a transition to net-zero carbon emissions, several sub-sectors related to energy generation will see substantial increases in jobs. These sub-sectors include new sources of electricity from hydro, wind and solar, nuclear, and fossil fuels[40] and jobs related to electricity transmission, control, and distribution. The number of jobs related to these sub-sectors would be 52,000 higher in 2050 than 2015 in the Electrons scenario, 41,000 higher in the Blended scenario, and 33,000 higher in the Resources scenario (see Table 5 on page 40).[41] For these jobs, process skills, like critical thinking and monitoring, and cross-functional skills, like problem solving and decision making, emerge as the most important skillsets. Unlike most other sectors, service orientation and systems analysis skills also feature in energy generation and distribution jobs. A quick look at the top occupations (those expected to experience the most growth by 2050, relative to 2015) associated with renewable or low-GHG energy jobs reveals some interesting insights related to variations within skills' importance (Figure 6). First, even within engineering occupations, technical skills like operations monitoring, operation and control, and quality control are more important for electrical engineers than for civil engineers. On the other hand, civil engineers require more operation analysis skills and more cross-functional skills like systems analysis and time management. The importance of operations monitoring is the highest for electrical operators. All skills needed by contractors/supervisors who oversee electricians and line workers have similar importance, but installation, troubleshooting, and repairing are more important for these professions than for other occupations.

40 While jobs in electricity generation from fossil fuels grows across all three scenarios, the growth is a very small chunk of the total job growth in these sectors. It is also smaller than it would be in the absence of decarbonization efforts. Job growth in this area is lowest in the Electrons scenario and greatest in the Blended scenario.

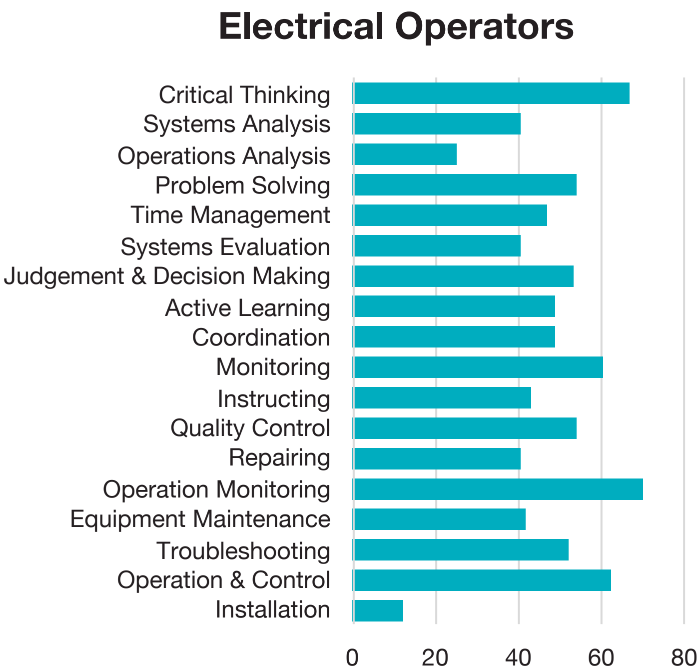
41 In this sub-section, we report the job numbers from Table 5, in which net job growth numbers are quoted as full-time equivalents to correct for sectors that have part-time workers. This is in contrast with aggregate job numbers used elsewhere in the report and the model results in Appendices 4 and 5, which report job growth numbers as total jobs, including both full-time or part-time. Using the full-time equivalent jobs category allows us to disaggregate the manufacturing sector in the model to analyze sectors such as machinery, and computers and electronics, which the total jobs categorization does not.

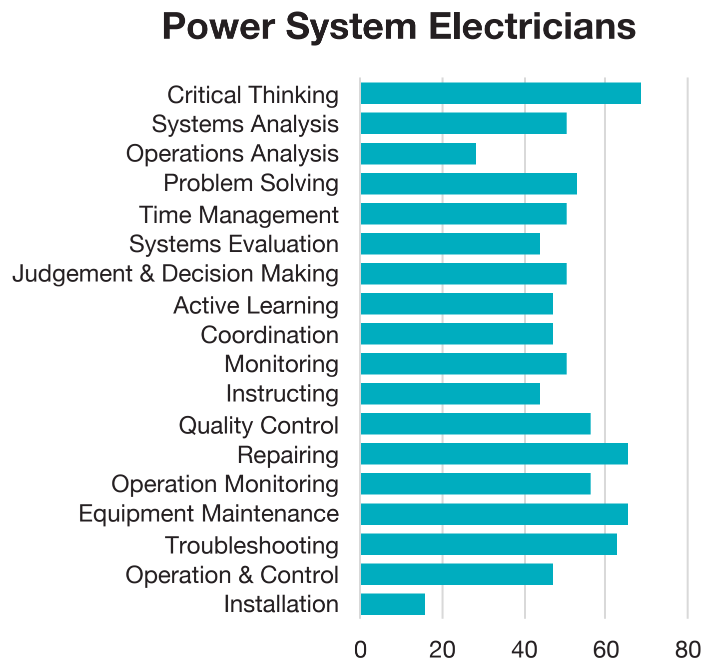
FIGURE 6

Skills needed by workers in electricity generation and distribution (absolute scores, 0–100)



Source: Drawn from United States Occupational Information Network (O*NET) and ESDC correspondence table between the National Occupational Classification (NOC) 2016 Version 1.3 and US O*NET





Source: Drawn from United States Occupational Information Network (O*NET) and ESDC correspondence table between the National Occupational Classification (NOC) 2016 Version 1.3 and US O*NET

ALTERNATIVE FUEL PRODUCTION (HYDROGEN AND BIOFUELS)

Alternative fuels, such as hydrogen and biofuel, will meet a large portion of Canada's energy demands in a decarbonized future. The modelling shows that the number of jobs related to hydrogen and biofuel production would grow by over 40,000 by 2050 in both the Electrons and Blended scenarios, but by only 9,000 in the Resources scenario (see Table 5 on page 40). Most of this growth is driven by hydrogen production from biomass gasification and natural gas reformation, but biodiesel production from canola seed and soybean feedstock also plays a part. Canada is among the world's top ten producers of hydrogen, which is an important component of Canada's pathways to net-zero emissions in 2050 as outlined in the federal government's Hydrogen Strategy for Canada (Natural Resources Canada, 2020).

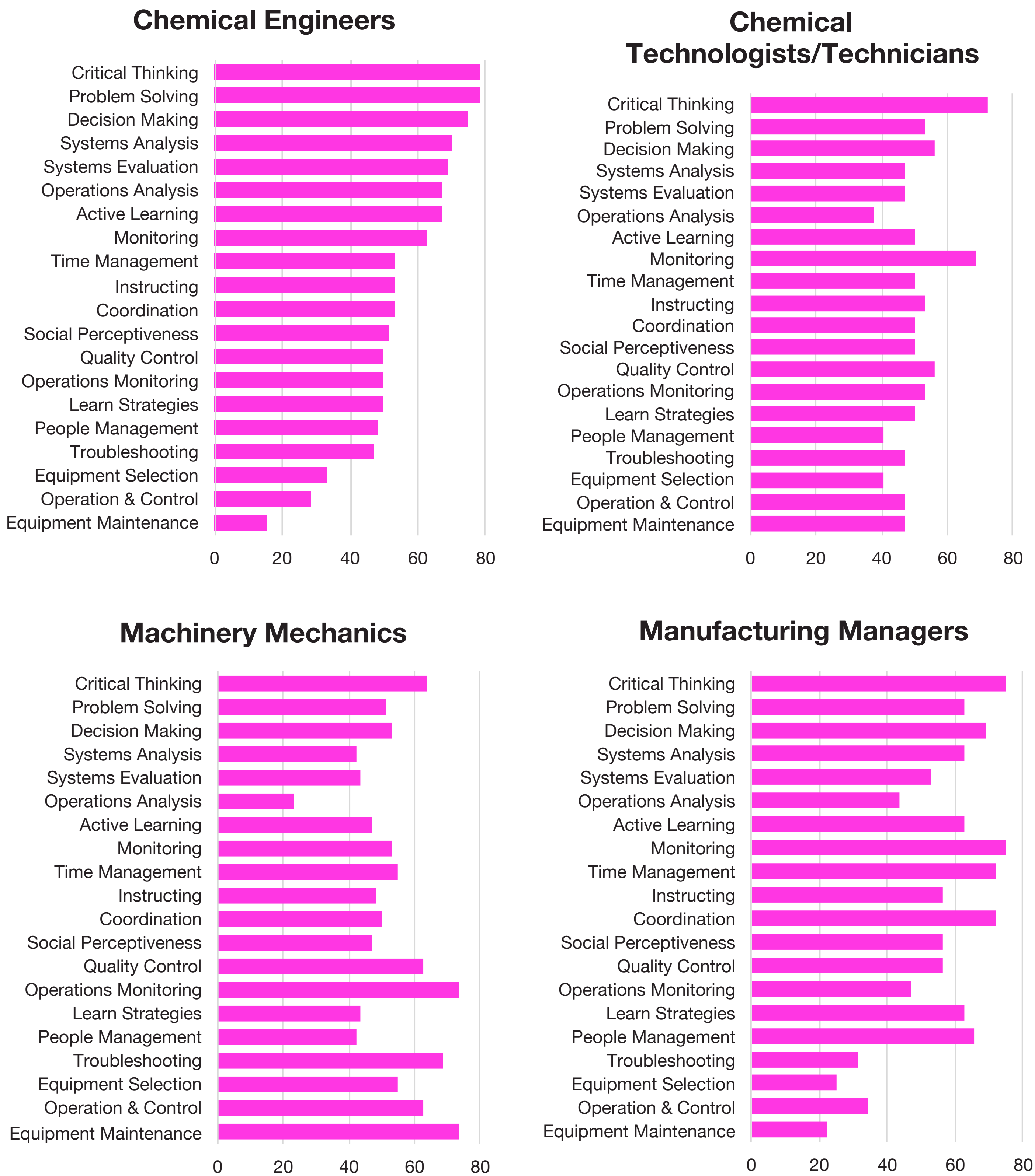
The skills profiles for jobs that will emerge in these alternative fuel sectors are similar to those of current occupations within the industrial gas manufacturing industries and chemical manufacturing sectors. Critical thinking, process monitoring, decision making, and problem solving feature as the most important skills in these sectors. Due to the complex nature of these occupations, active learning is another skill that is highly valued in these roles. The variation in the skills requirements of these workers also reveals interesting insights.[42] Machinery mechanics require some core technical skills, including the ability to repair and maintain equipment, troubleshoot, and monitor operations. Workers who operate chemical plant machines have a very similar skills profile, including controlling the operations of equipment and systems (Figure 7).

Across all sectors of the future, management roles will become increasingly important. In alternative fuels, these will be manufacturing managers, mechanical engineers, and chemical engineers who will be more involved in decision-making processes. Managers require more management, monitoring, and coordination skills, while mechanical and chemical engineers require skills related to the design of technology, operations and systems analysis, and systems evaluation. However, it is important to note that several of the jobs expected to be created in alternative fuel production, including hydrogen, will be new jobs that currently do not have associated titles within the NOC handbook or associated skills profiles within the O*NET database, as the tasks associated with these roles remain unknown. Nevertheless, many of these jobs are expected to require a broad range of qualifications and skills that are currently already employed in manufacturing jobs (Bezdek, 2019). In the future, as more of these positions emerge and their skills requirements solidify, databases like the NOC and O*NET will be updated, which should enable more precise analysis.

42 For a deeper dive into a handful of occupations across sectors, we looked at their employment shares in 2019 as well as literature that argues how jobs will evolve across various skill levels (i.e., high skill level, medium skill level, and low skill level). The jobs cover a range of skills requirements from management, technical and engineering, and supervisory skills (ILO, 2019).

FIGURE 7

Skills needed by workers in alternative fuel manufacturing (absolute scores, 0–100)



Source: Drawn from United States Occupational Information Network (O*NET) and ESDC correspondence table between the National Occupational Classification (NOC) 2016 Version 1.3 and US O*NET

BOX 3

Leveraging skills in a decarbonized world: The curious case of Alberta

As Canada shifts to a net-zero emissions economy, it is expected that provinces such as Alberta will lose jobs in traditional fossil fuel sectors. However, examples such as the Halkirk Wind Project and Living Energy Project are cases where existing skills profiles of workers in Alberta can be leveraged for jobs in newer and cleaner energy production.

Halkirk Wind Project:
Alberta boasts the best wind and solar resources in Canada. These sectors are expected to generate substantial numbers of new jobs in construction, operation, and maintenance, all of which can be undertaken by the existing labour force with the help of some re-training. An example of this is the 150 MW Halkirk Wind project in Alberta. During the construction phase, the project employed 270 workers, including electrical workers, masons, and ironworkers (Power Technology, 2013). It continues to employ workers for maintenance and operation (Bridge & Gilbert, 2017). As illustrated by this example, transition programs can focus on leveraging the strengths of the existing skillsets of workers expected to lose their jobs in the oil and gas sectors for jobs that are expected to be created in the wind energy sector. Moreover, essential skills like project management, installation, repairing, monitoring, and coordination—skills required for oil and gas workers—can, aided by other factors like effective re-training programs, help with a smoother transition.

Living Energy Project:
Canada is home to many leading geothermal power developers (CanGEA, 2016). While geothermal is a cheap form of energy in the long run, drilling for geothermal wells entails significant risks and upfront costs. Existing oil and gas wells (with high bottom temperatures) can be repurposed to create geothermal heating systems, and thus significantly reduce the risks of those project. This will create jobs in well exploration, drilling, and construction of end-use facilities. The Living Energy Project in Alberta proposes to convert 78,000 dormant wells for geothermal heating systems for greenhouses. This project could create up to 5,000 permanent agriculture jobs and work for thousands of oil service workers, allowing these workers to recycle their skills and training for cleaner energy production (Alberta Oil Magazine, 2016).

Moreover, the Alberta Electric System Operator conducted long-term outlook forecasting for electricity demand and generation to 2030 in multiple energy demand scenarios. Two of these

BOX 3 (CONTINUED)

Leveraging skills in a decarbonized world: The curious case of Alberta

scenarios entailed alternate renewable policy and a diversification scenario, with the former resulting in the creation of 10,400 jobs and the latter resulting in the creation of 31,800 jobs in 49 solar and wind generation projects. These jobs would include mechanical, electrical, civil, and design engineers. These professions will require skills such as technological design, operations analysis, problem solving, systems analysis, and systems evaluation. In addition, jobs related to construction, operation, and maintenance will be created throughout the project lifecycle (Kaddoura et al., 2020).

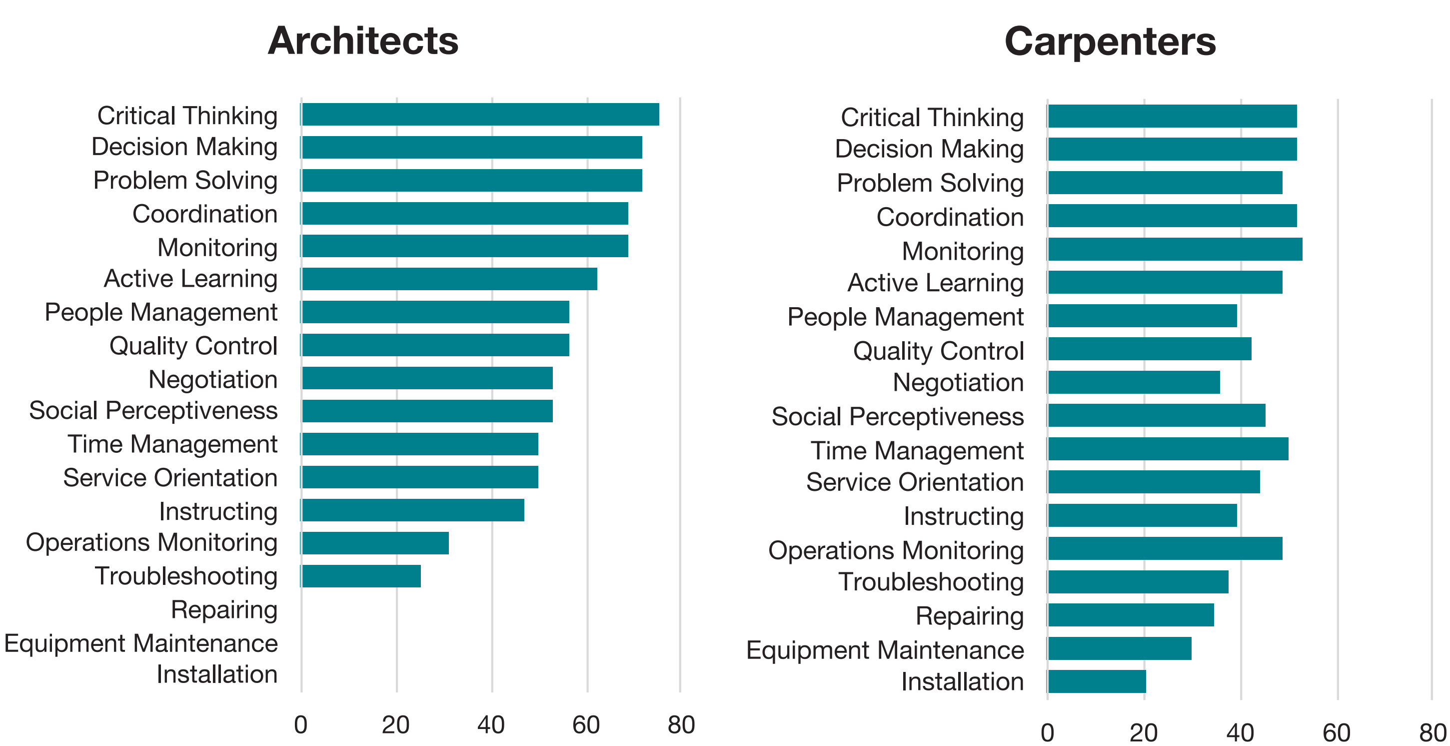
These examples show that, given the right projects and retraining, oil and gas workers in Alberta can reuse and recycle their skillsets for cleaner energy projects that are consistent with the net-zero emissions goal. However, it is likely that the workforce in Alberta will face some structural unemployment or underemployment during the transition phase. Programs such as transition funds, social safety nets, wage subsidies, and effective skills programs that allow workers to use their existing skills for new tasks will become more relevant. Therefore, it is important to appropriately harness the potential of these jobs to make Canada’s net-zero transition sustainable in the long run.

Construction

Across all decarbonization pathways, jobs in the construction sector are expected to grow by anywhere from 128,000 to 188,000 positions between 2015 and 2050 (see Table 5 on page 40). In a decarbonized future, the construction sector will witness significant structural changes, with increasing demand for generic skills, like energy conservation, that will be applied for tasks such as retrofitting buildings. Operations monitoring and quality control are the most important technical skills in this sector, even though skills like installation and equipment selection rank relatively higher than they do in other sectors. Only a few occupations, namely electricians and plumbers, have a skills profile where technical skills like troubleshooting and repairing are more important than other skills. This supports the argument that the skills for a net-zero future are not necessarily unique skills. Rather, tasks like retrofitting buildings will most often require the application of existing technical skills to new tasks (Dierdorff et al., 2011). Occupations that account for the largest share of the construction workforce—construction managers, plumbers, electricians, carpenters, and contractors—reflect similar patterns (Figure 8). Skills related to communication and cooperation are often cited as a critical gap, as tradespeople are usually not part of decision-making processes (Canada Green Building Council, 2019). However, given the collaborative nature of low-carbon construction projects, it will become critical for all workers involved in the construction sector, from managers and architects to electricians and carpenters, to possess a similar broad-based skillset, especially as it relates to social skills and project management skills.

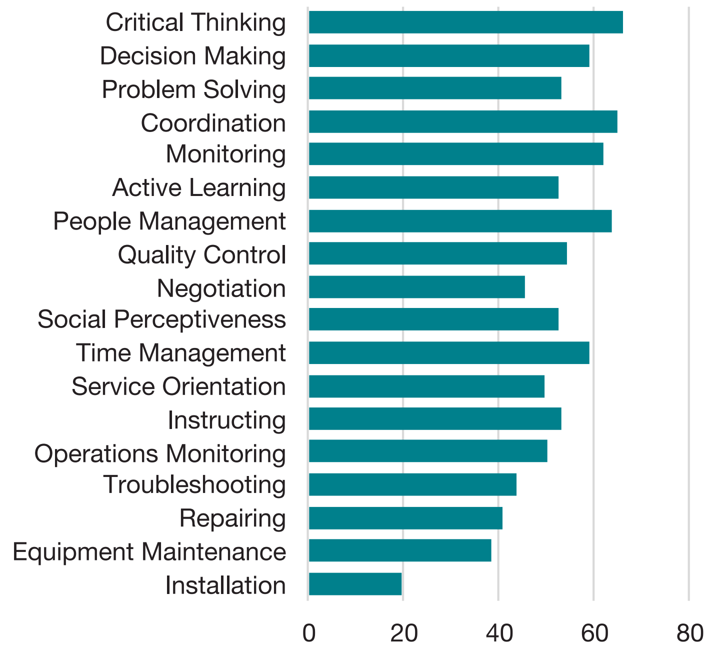
FIGURE 8

Skills needed by workers in construction (absolute scores, 0–100)



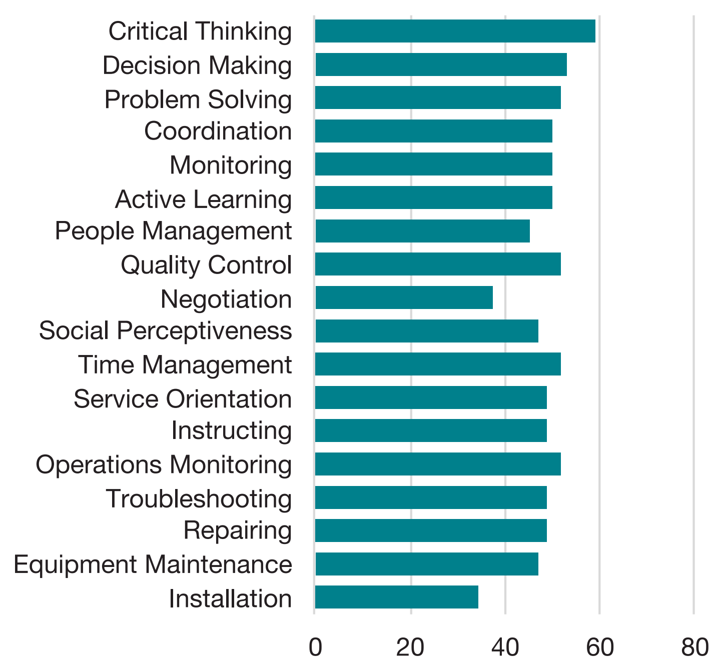
Construction Managers

Contractors/Supervisors



Electricians

Plumbers



Source: Drawn from United States Occupational Information Network (O*NET) and ESDC correspondence table between the National Occupational Classification (NOC) 2016 Version 1.3 and US O*NET

Electronics and electrical equipment manufacturing

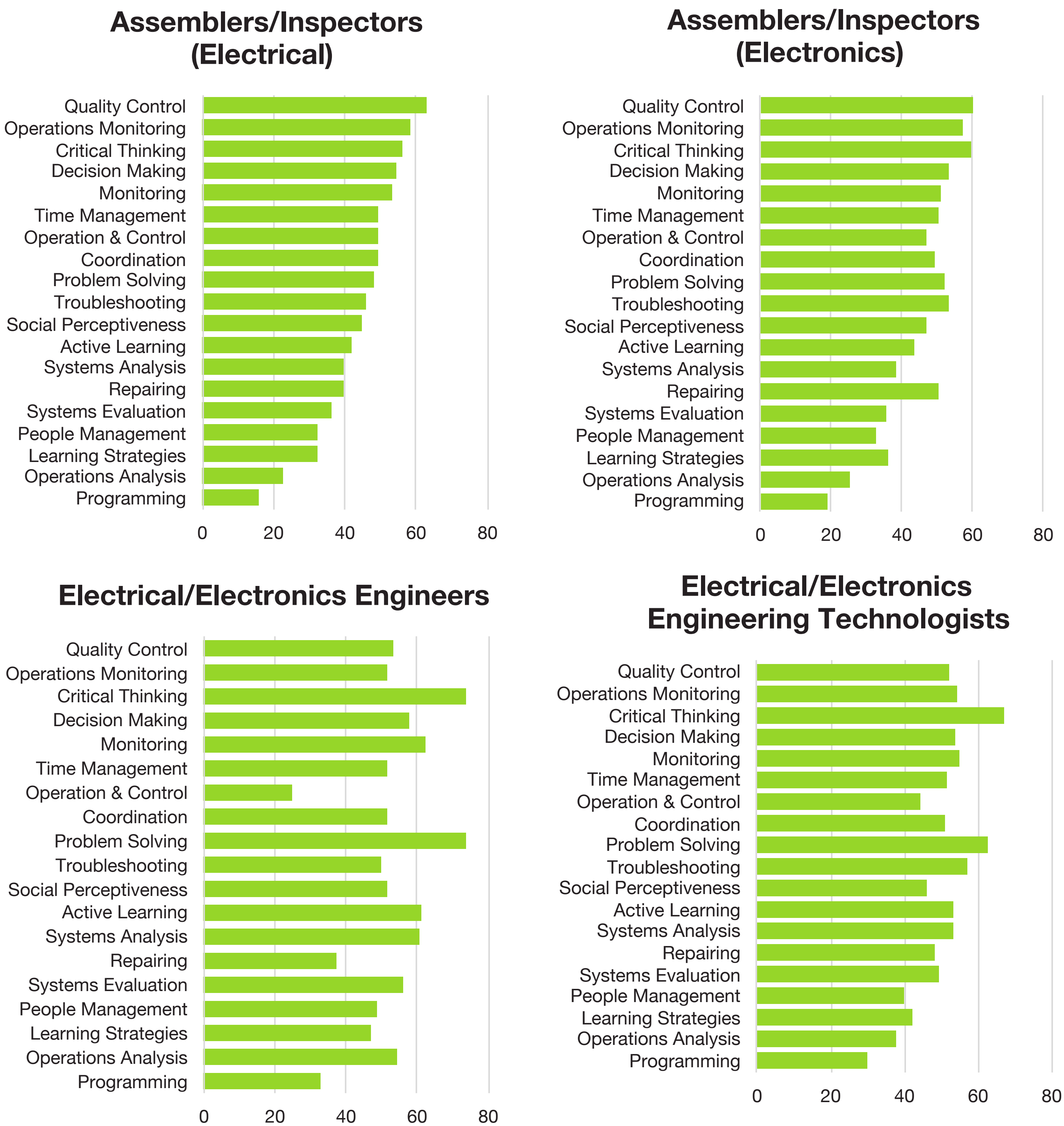
The number of jobs in the manufacturing of computers, electronics, and electrical equipment is expected to increase by 67,000 in the Electrons scenario, by 50,000 in the Resources scenario, and by 39,000 in the Blended scenario (see Table 5 on page 40). The new production processes in this sector will utilize low-carbon inputs for equipment manufacturing and incorporate circular economy practices[43] across manufacturing processes.

Overall, workers in these sectors require technical skills like quality control, systems analysis, programing, and operation and control. Other broad-based skills, however, also feature prominently for manufacturing managers, electrical and electronics engineers, and inspectors, whose skills profiles lean more heavily toward problem solving, decision making, and management. In a future characterized by increased automation and circular economy considerations, workers in the manufacturing industry will require a broad-based skillset of technical and non-technical skills to allow them to work effectively with a diverse workforce, adapt to newer technologies, and collaborate to solve problems.

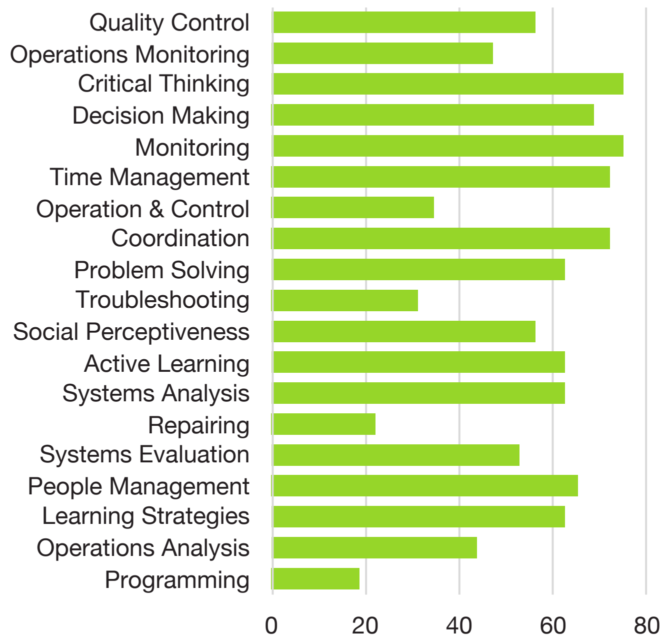
43 Circular economy practices look beyond the take-make-"waste" linear model of growth to mainstream principles that minimize waste and pollution, retain products and materials in use, and regenerate natural systems.

FIGURE 9

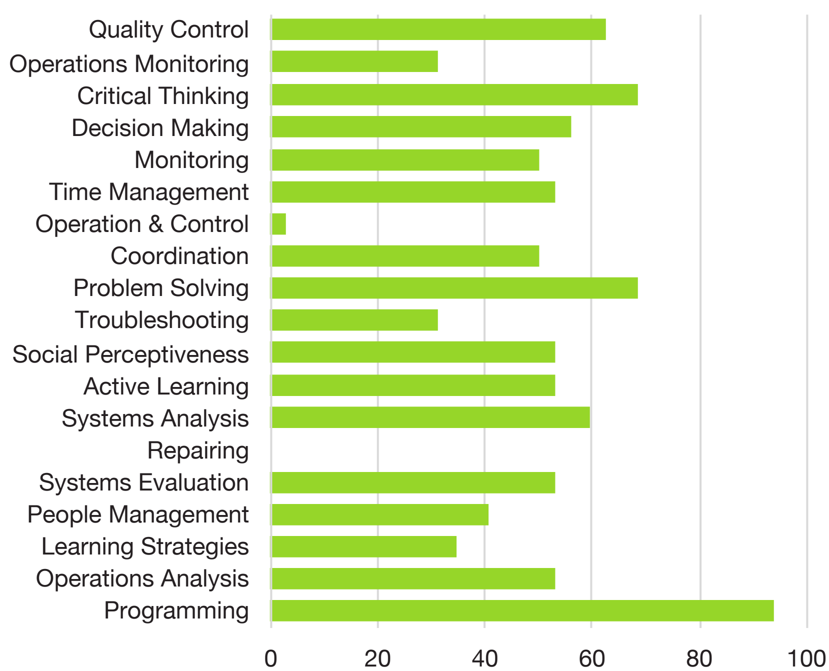
Skills needed by workers in electronics and electrical equipment manufacturing (absolute scores, 0–100)



Manufacturing Managers



Programmers/Media Developers



Source: Drawn from United States Occupational Information Network (O*NET) and ESDC correspondence table between the National Occupational Classification (NOC) 2016 Version 1.3 and US O*NET

Machinery manufacturing

A lower-carbon-intensity pathway to decarbonization (Electrons) will see the largest increase in the number of jobs in machinery manufacturing by 2050 (89,000), while a middle-ground pathway (Blended) will see the least increase in this number (45,000). A portion of this increase in jobs will be driven by low-carbon machinery, with an increase ranging from 11,000 to 15,000 jobs between scenarios (see Table 5 on page 40). These jobs would be involved in the manufacturing of electric motors and compressors, industrial heat pumps, and high-efficiency natural gas-fired boilers.

The largest share of workers involved in manufacturing machinery is composed of welders and workers in metal fabrication, with both categories requiring the same

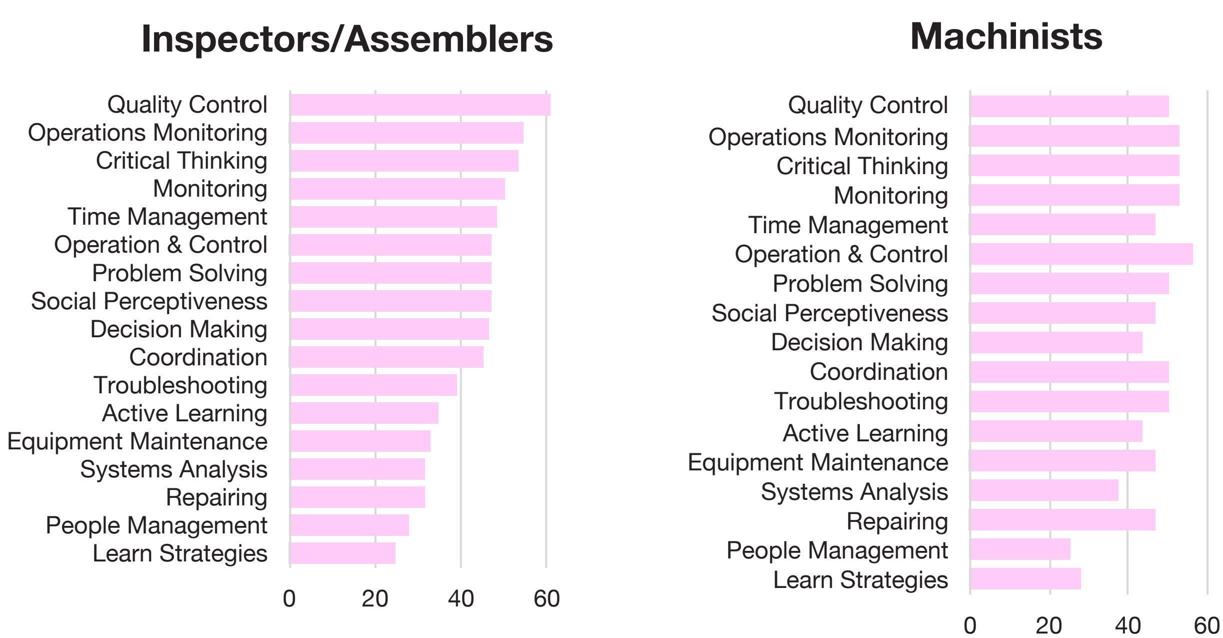
The vast increase in jobs in this sector will also be characterized by a shift from manual labour to automation and by innovation that will threaten the existing skillsets of jobs, including in welding and metal fabrication.

set of technical and non-technical skills (Figure 10). On the other hand, manufacturing managers and supervisors require a skillset for which non-technical skills hold far more importance, including monitoring, coordination, and managing time and people.

Importantly, however, the vast increase in jobs in this sector will also be characterized by a shift from manual labour to automation and by innovation that will threaten the existing skillsets of jobs, including in welding and metal fabrication. This would mean such lower-skill-level jobs may be at least partially replaced by jobs characterized by higher skill levels, such as mechanical engineers, industrial and manufacturing engineers, and computer programmers. These higher-skill-level occupations are associated with skills that have higher importance scores for skills like programming, technical or technological design, problem solving, decision making, and critical thinking.

FIGURE 10

Skills needed by workers in machinery manufacturing (absolute scores, 0–100)



Manufacturing Managers

Metal Fabricators

Supervisors

Welders

Source: Drawn from United States Occupational Information Network (O*NET) and ESDC correspondence table between the National Occupational Classification (NOC) 2016 Version 1.3 and US O*NET

Transportation equipment manufacturing

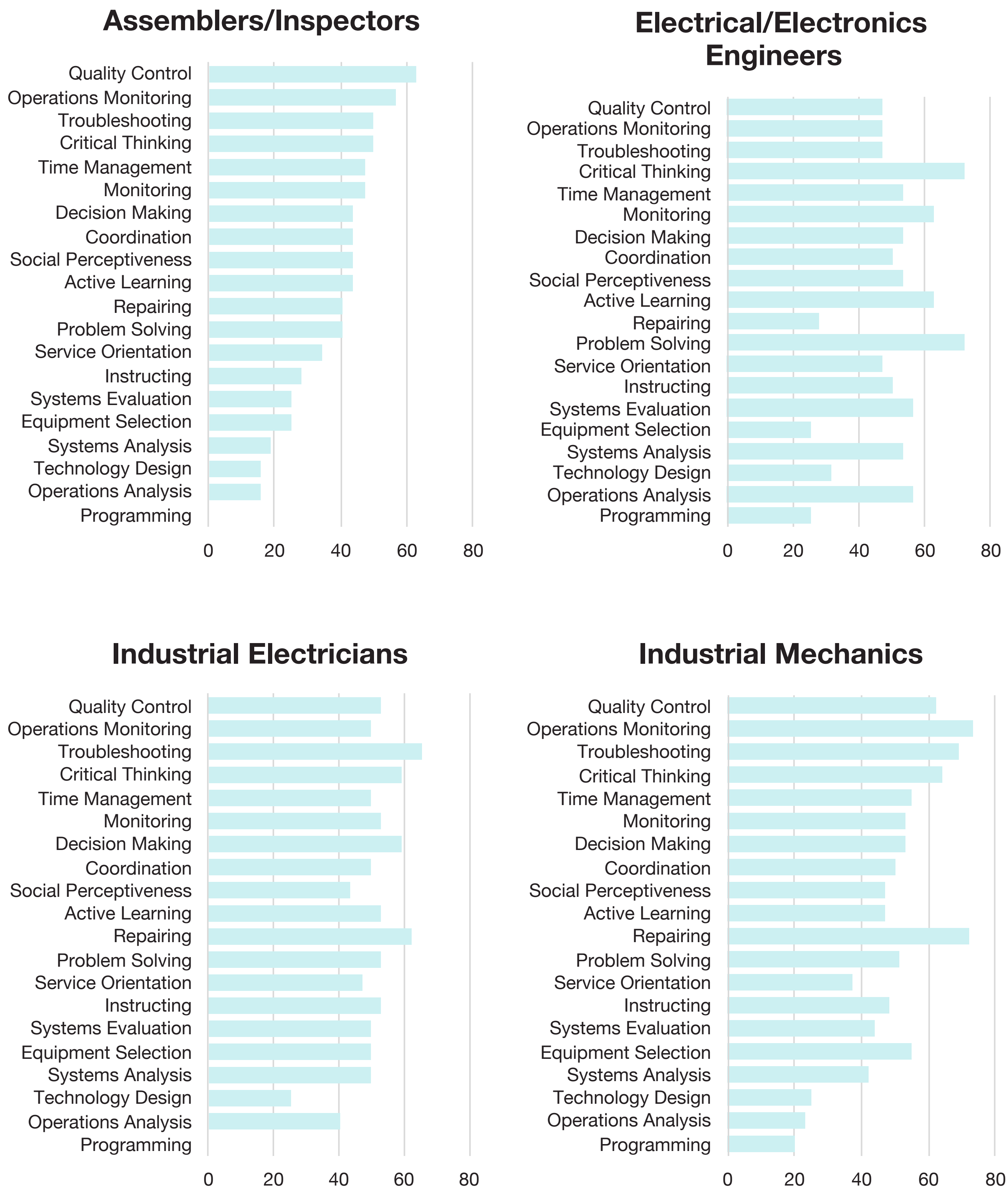
Workers in transportation equipment manufacturing will see 26,000 more jobs in this area in the Resources pathway to decarbonization and 20,000 more in the Electrons pathway. The transition of vehicle manufacturing in Canada is expected to be transformative and substantial. This transition will be driven by the replacement of vehicles with internal combustion engines by electric vehicles. As is the case for most technological innovations, some new jobs in one area will replace old jobs in others. Yet while electric and hybrid vehicles will replace manufacturing of internal combustion engines and traditional automotive mechanical work, the manufacturing of electric vehicles does not differ at a structural level from the manufacturing of vehicles with internal combustion engines. Thus, these processes do not differ significantly in relation to the workers' skillsets involved. Nonetheless, the contributions of roles like mechanical engineers, technologists, and software engineers will change as programming and technology design skills, as well as skills related to battery management, increase in importance (Matchtech, 2016).

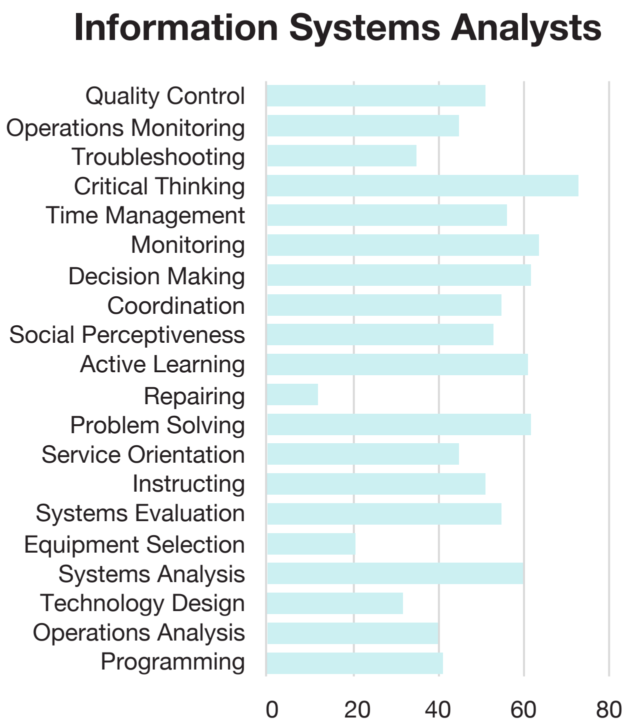
It is important to acknowledge that while the transition of the automotive sector is expected to be transformative, it will include its own set of challenges in relation to employment and skills unless it is accompanied by a strategic set of investments and policies. In addition to retooling assembly lines and expanding the supply chain for manufacturing electric vehicle components, it is also estimated that most of the jobs created in the electric vehicle industry will be classified as high-skill-level jobs (such as battery technicians). This transition to demanding a larger number of higher-skill-level jobs would also change the nature of the work that goes into maintaining and repairing electric vehicles and the associated infrastructure (Kopperson et al., 2014; The Economist, 2021).

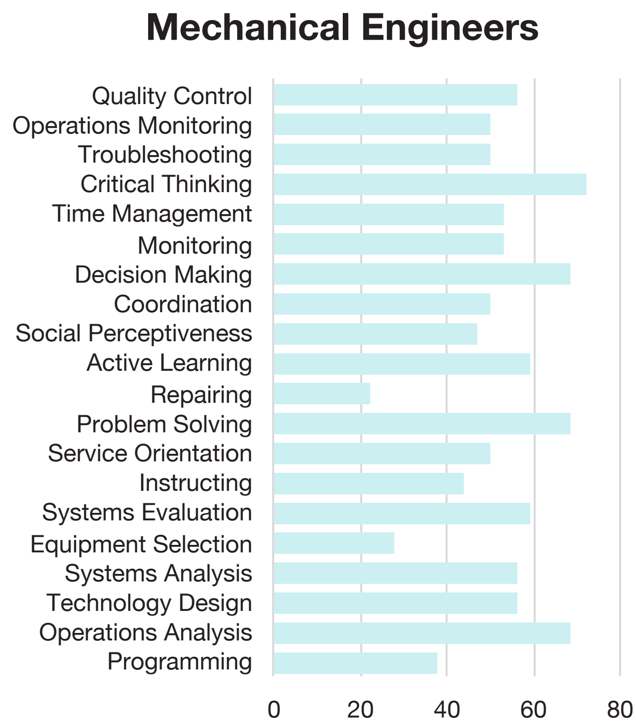
While electric and hybrid vehicles will replace manufacturing of internal combustion engines and traditional automotive mechanical work, the manufacturing of electric vehicles does not differ at a structural level from the manufacturing of vehicles with internal combustion engines.

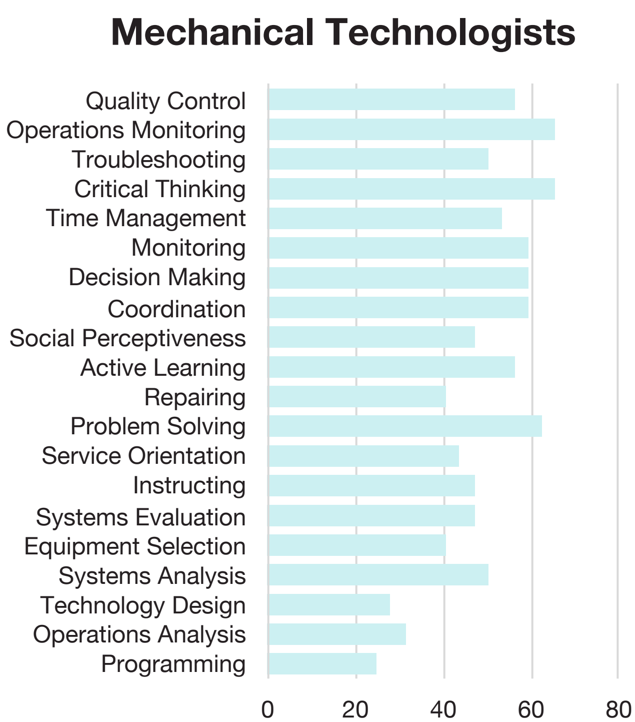
FIGURE 11

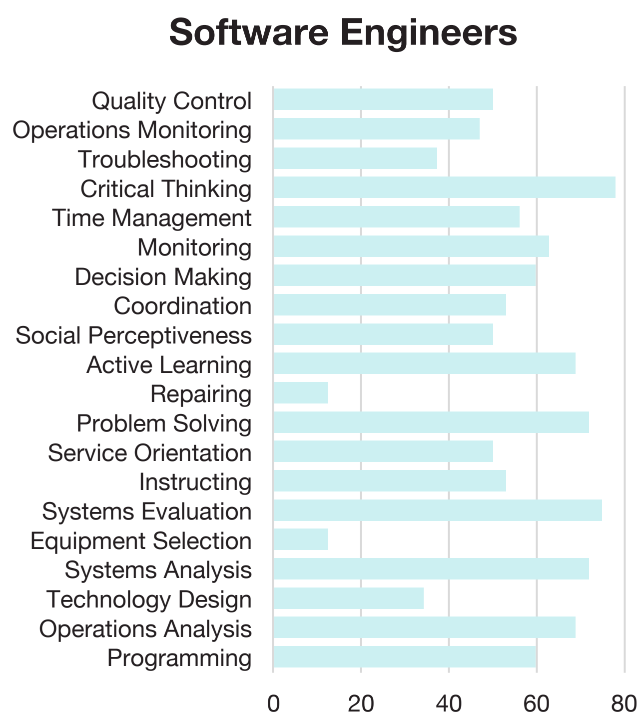
Skills needed by workers in transportation equipment manufacturing (absolute scores, 0–100)











Source: Drawn from United States Occupational Information Network (O*NET) and ESDC correspondence table between the National Occupational Classification (NOC) 2016 Version 1.3 and US O*NET

Direct air capture

Direct air capture (DAC) is a technology that uses electricity and heat to capture carbon dioxide (CO_2) from the air for use—in the food, beverage, and chemicals sectors; for enhanced oil recovery; and for cement and carbon fiber manufacturing—and storage underground.[44] This is a new sector that our modelling identifies as having significant potential for job creation. Since the lower-carbon-intensity Electrons pathway is less reliant on emitting GHG in the first place, this scenario witnesses the least growth in jobs in this sector. Even so, by 2050, 69,000 jobs are expected to be created in the Electrons scenario, 75,000 are expected in the Blended scenario, and close to 150,000 jobs are expected in the higher-carbon-intensity Resources pathway (see Appendix 4).

In June 2020, the Rhodium Group, a research organization, published a study exploring the economic potential of DAC in the United States, including its impact on jobs. The construction of DAC plants will directly impact jobs in several other sectors, including construction; cement, steel, industrial equipment manufacturing; engineering; operation and maintenance; and power generation. These jobs will be needed to construct and maintain DAC facilities and will be associated with a broad range of skills across key sectors discussed in this report. An analysis of the job creation potential of DAC in the United States reveals that a majority of the jobs expected to be created are associated with the design, engineering, and construction of DAC facilities as well as the manufacturing of equipment for these facilities. It is also estimated that a typical facility will require over 250 workers to operate and maintain it (Larsen et al., 2020). To construct the facility, jobs related to industrial equipment, steel, and cement manufacturing; construction; architecture; and engineering will be needed. Broadly speaking, a wide set of skills is required in these sectors including critical thinking, monitoring, coordination, decision making, and time management (see Table 4 for details of the skills needs for these sectors).

The operation of a DAC facility will create new jobs related to commercial and industrial machinery and equipment repair and maintenance. Operation and control, operations monitoring, systems analysis, and systems evaluation are some of the skills that will be relevant for these specific jobs. Jobs associated with electric power generation, natural gas, and chemical manufacturing will also be needed, meaning that a wide range of technical and, importantly, non-technical skills identified in this section will be required in this sector. Developing a better understanding of how these roles will emerge and evolve will allow policy-makers and other stakeholders in the skills training and development ecosystem to meet the demand for skills in this sector.

44 Carbon Engineering is a Canadian clean technology company that aims to develop and commercialize DAC technology to pull carbon dioxide directly from the atmosphere. Their pilot plant in Squamish, British Columbia, has the capacity to capture approximately 1 tonne of atmospheric CO_2 per day (Carbon Removal Technology, Carbon Engineering).

BOX 4

What is the impact of carbon offsetting on skills and labour in the Blended scenario?

This report models three distinct and credible pathways to a decarbonized future in Canada. Two pathways (Electrons and Resources) assume that net-zero emissions are achieved directly through a mix of technologies that either reduce GHG emissions at source or compensate for them through CO_2 capture and storage (CCS/CCUS). The third pathway (Blended) assumes that technology take-up will be responsible for exactly 75% of emissions reductions, while the rest will be offset in other jurisdictions. This means that emissions in 2050 are directly reduced by 75% from their 2005 levels in the Blended scenario, with the remaining 25% (187 Mt CO_2e) indirectly reduced through carbon offset schemes.

Carbon offsetting is a market-based policy involving activities to reduce GHG emissions that compensate for emissions emitted by another source. There are two types of markets for carbon offsets: voluntary and compliance. Voluntary markets allow individuals and companies to purchase carbon offsets to compensate for their carbon footprint and are not generally connected to regulatory compliance requirements. Compliance markets are set up and regulated at the international, regional, or national level to support regulatory compliance (Carbon Offset Guide, n.d.).

Identifying that offsets will be used for emissions reductions is a valid external policy assumption given that numerous offsets schemes already exist and that other efforts are underway around the world to introduce additional national and regional compliance carbon offset schemes. Nonetheless, the 25% of emissions reductions assumed to be offset in this Blended scenario is not included in the modelling for several reasons. First, while some existing regional protocols, like the Exchange Trading System in the European Union, already incorporate carbon offset schemes, the dynamics and structures of such schemes, including quantification of emissions reductions, differ for each market, making them difficult to model or include outside of a single market in sophisticated analyses. As well, these mechanisms for international schemes are as yet undefined by the United Nations Framework Convention on Climate Change (Dion et al., 2021). Second, and due to the significant uncertainty just described, it is currently unclear what types of jobs will be created through these offset schemes.

In Canada, the Federal Greenhouse Gas Offset System is currently being developed to allow farmers, foresters, municipalities, and companies to generate and sell carbon credits across

BOX 4 (CONTINUED)

What is the impact of carbon offsetting on skills and labour in the Blended scenario?

the country. The system, which is voluntary, includes defining federal offset protocols to quantify GHG reductions for the given project types. These project types include:

> Advanced refrigeration systems

> Landfill methane management

> Improved forest management

> Enhanced soil organic carbon (Government of Canada, 2021)

Broadly, the offset projects that will be eligible under this system are expected to occur in the agriculture, forestry, and waste management sectors.

While there is a lot of uncertainty regarding the types of jobs and skills that will be impacted by this voluntary domestic system—thus making it difficult to model[45]—it is expected that demand for projects in these sectors will rise as the financial benefit of investing in them increases. Consequently, the number of jobs created by the market for offsetting GHG emissions—jobs that will likely be distributed across a wide variety of professions—will likely rise. Indeed, in addition to workers central to the core project operations in these sectors, workers will also likely be needed to ensure compliance with the offset system as well as to reduce costs while maximizing net financial gains from the sale of carbon offset credits.

While it is not possible to model increases in the number of jobs created by offsets, there is already evidence that these numbers, as well as the other benefits that flow from these projects, will be significant. In 2014, a survey of 59 offset projects in voluntary offset programs around the world concluded that up to US$664 in value of environmental, social, and economic benefits may be realized for each tonne of CO_2 that is offset, in addition to other business-specific benefits. Most of these projects were related to afforestation/reforestation; replacement of inefficient cookstoves with cleaner, safer, and healthier burning ones; REDD[46]/avoided conversion; and domestic bio-gas. Around 1,467 jobs were created in the development phases of these projects, while 8,042 of them were created for their operation (ICROA & Imperial College, 2014).

45 Understanding the job creation potential of domestic offset programs in Canada is a potential avenue for future research.

46 REDD stands for "reducing emissions from deforestation and forest degradation" and is a global program negotiated by the United Nations Framework Convention on Climate Change to mitigate climate change by reducing net GHG emissions through enhanced forest management.

SECTION 7: Conclusions and Recommendations

Supporting a net-zero transition through policy

The transition to a net-zero economy is expected to have a significant impact on the labour market in Canada. Across scenarios that are more reliant on carbon as well as those that are less reliant on carbon, the number of jobs in the Canadian economy continues to grow. In fact, the scenario with the most aggressive carbon-reduction pathway is actually also the scenario in which the most jobs are created, albeit marginally so. However, it is important to re-iterate that the scenarios presented in this report only offer insights into the economic impact of varying decarbonization scenarios. That is, the analysis presents the labour market impacts of a foresight exercise that allows us to confront the contours of plausible future scenarios, and the similarities across these scenarios, without actually predicting the future. The actual path that Canada embarks upon will be determined by the conscious policy choices made by the government, decisions taken by businesses to leverage opportunities and minimize risks, and global markets and transition pathways. Consequently, the precise quantitative results of these decisions will almost certainly be different than what has been presented here. While the insights generated here are designed to be helpful aids in navigating this transition, the exact mix of policies and decisions that will determine how successfully the transition is managed will come from all stakeholders grappling with actual developments and uncertainty in real time.

Even with these important qualifications in place, the limited differences found in job creation across the scenarios modelled here underscores the fact that the vast majority of jobs in the Canadian economy—approximately 75%—will not be directly affected by decarbonization, as these jobs are in sectors that are neither energy-intensive nor GHG-intensive (e.g., retail, finance, healthcare, education, and services). However, jobs will grow in clean energy sectors irrespective of the pathway that Canada takes to decarbonize and the workers who take up these jobs will require a breadth of technical and non-technical skills. Identifying these skills facilitates the task of preparing the workforce to acquire them and easing their transition from one set of jobs to another.

While, from a jobs perspective, the difference in impacts on the workforce between each pathway might be limited, these aggregate national numbers obscure significant changes under the surface. As we have seen, a number of jobs will migrate from carbon-intensive sectors like oil and gas to sectors like manufacturing, construction, clean energy, transportation, and CCS/CCUS, where new green approaches are taking hold. This trend is reflected across provinces, albeit with some variation. The net gains in jobs in manufacturing and construction are greatest in Ontario and Alberta. Jobs related to DAC will emerge in Canada across scenarios and will be the highest in number in Alberta. These structural changes in jobs will have a number of significant implications for the skills development and training ecosystem. More specifically, the analysis conducted in this report has uncovered a number of key findings that should help Canadians navigate the impacts of the drive to net-zero on skills, including:

> **Technical and non-technical skills will be equally important in a net-zero future.** The importance placed on non-technical skills in the net-zero transition cannot be overemphasized. In their provincial reports on equipping the trades with skills of the future, the Canada Green Building Council has stressed that social or interpersonal skills—like coordination, communication, and time management—when combined with technical skills, result in the "green literacy" that workers need to deliver effective low-carbon infrastructure solutions (Canada Green Building Council, 2019). These skills are often required across all roles, regardless of their general skill level, and encompass the ability to communicate ideas, negotiate changes, coordinate across team members, and solve complex problems. Workers who are able to become part of a successful transition will be able to re-use these transferable skills in new occupations provided they are given the requisite support (ILO, 2019).

> **Social and cognitive skills will be vital.** The top five skills that rank as fundamental for the workforce in a green transition include critical thinking, monitoring, coordination, judgement and decision making, and complex problem solving.

> **Skills aligned with a net-zero economy are not new skills, but a strategic recycling of existing skills.** To develop effective policies for skills, it is important to recognize that skills for a decarbonized future are not necessarily new skills, but rather the application of existing skills to new tasks considered central to advancing the economy to a net-zero emissions future. Existing technical skills such as operations monitoring and quality control stand out in sectors that are important for a decarbonized economy, including construction, manufacturing, and DAC technologies. These are not unique skills. Rather, they are existing skills being used to complete tasks across a range of both clean and traditional occupations. This finding supports previous arguments that green skills are mostly the application of existing skills to new green tasks (Dierdorff et al., 2011). It is true that this may not always be the case, especially

for emerging sectors such as hydrogen and biofuel production and emissions capture and control. Occupations in these sectors are currently evolving, and their tasks and required skills, knowledge, and qualifications are not formally established in federal and provincial career handbooks (Bezdek, 2019). Yet it is also true that these new occupations, like carbon capture technicians and hydrogen fuel cell designers, will still require a combination of traditional technical skills (like installation and technology design) and social skills typically required in other occupations, such as social perceptiveness, coordination, management, and service orientation.

> **Workers across provinces have different transition needs.** Our modelling results depict considerable heterogeneity in jobs gained and lost across provinces. Workers in Alberta and Saskatchewan are particularly vulnerable to losing jobs as these dry up in fossil-fuel-intensive sectors and emerge in sectors pertinent for a decarbonized future. Even in the Resources scenario, we see the number of jobs in the oil and gas sector in Alberta fall. However, it is important to note that these jobs are being replaced by jobs in other sectors. This means that one of the most important ways to support workers in provinces like Alberta would be to provide skills support to transition from one category of jobs to another. One way to do this would be to design skills retraining programs that would allow workers from the oil and gas sector to effectively perform tasks in green occupations. For example, occupations in renewable energy, as well as carbon capture and storage, require many of the same skills as occupations in mining, and oil and gas.[47]

The top five skills that rank as fundamental for the workforce in a green transition include critical thinking, monitoring, coordination, judgement and decision making, and complex problem solving.

> **Sectors that gain jobs and those that lose jobs share common skills needs.** There are commonalities in skills across occupations in sectors that gain jobs and those that lose jobs. Appendix 6 highlights occupations in natural-resource-intensive sectors that are set to lose jobs in a net-zero world across the three decarbonization scenarios in 2050. The greatest job decreases are seen

47 Direct air capture and storage jobs and jobs in renewable energy projects engage a similar portfolio of workers: plant operators, a broad range of engineers, machinery mechanics and technicians, and managers. Carbon capture technicians, for example, require not only an engineering background, but also experience in the mining, and oil and gas sectors as well as HVAC maintenance. In addition to these skills, complex problem solving and attention to detail are also important (Canadian Scholarship Trust Consultants, 2017).

in animal production and aquaculture, followed by farming, and oil and gas extraction. In terms of their importance, the top skills in the sectors that shed jobs are similar to those in sectors that gain jobs. These common skills include critical thinking, active learning, problem solving and social skills such as coordination, decision making, and time management. The skills that vary include instructing, troubleshooting, and people management, all of which are more important in resource-intensive sectors. The key takeaway is that workers who may lose jobs across decarbonization scenarios will largely possess the skillsets they will need to perform tasks in jobs that will emerge across a range of decarbonized futures. The key will be to design targeted retraining plans that show workers how their existing skills can be applied to new jobs and quickly and efficiently provide them with whatever increments of new knowledge or job-specific technical training they require to transition to these new sectors as effectively and seamlessly as possible.

Coordinated action by policy-makers, educational institutions, and employers is needed to support as smooth a transition as possible of workers from one set of opportunities to another. This report reveals a few interconnected implications and recommendations for developing skills policies to respond to Canada's net-zero commitments, outlined below.

Policy Action 1: Develop a net-zero aligned career roadmap based on bridging labour market information and data gaps.

Many of the new jobs emerging as a part of the transition to a net-zero economy are medium- to high-skill-level positions. However, even lower-skill-level roles will require more environmental awareness and process adaptation. A green career roadmap that aims to transition workers between opportunities and ensure employers can access the regionally- and sector-specific skills they need would provide coordinated and strategic direction to designing reskilling and upskilling initiatives for a low-carbon future. Canada's commitment to achieving net-zero emissions by 2050 will be successful only if the affected workers can identify gaps in their skillsets and access to a broad range of information to address these gaps (Bonen & Oschinski, 2021). This includes access to education and training programs as well as access to a central repository that provides information about the low-carbon jobs that are anticipated to emerge in the future. A comprehensive career roadmap is needed that brings together:

- A skills database that is as comprehensive as the O*NET but responds to Canada's evolving need for skills for a green future
- Tools for individual workers to identify skills gaps
- Access to information about training programs
- An easily accessible platform for low-carbon job postings

Policy Action 2: Design reskilling and upskilling programs that respond to changing demographics, including provincial programs for workers in transition.

A one-size-fits-all skills development policy will not work for Canada's diverse population. Canada's workforce includes older workers who may find it hard to find work, new graduates with degrees but little on-the-job training, and foreign workers with a wealth of skills but a lack of Canadian experience, as well as other distinct groups with their own specific challenges. Designing skills programs that target these and other areas of potential unemployment or underemployment in Canada will be essential to ensuring that workers from all communities have the support they need to enter or re-enter the labour force. These programs should also be regionally differentiated to ensure the needs of, for example, oil and gas workers in Alberta are not inadvertently assumed to be identical to those working in manufacturing in Ontario and Quebec.

Policy Action 3: Create training programs that emphasize the importance of social and cognitive skills for future work.

The most important non-technical skills identified in this analysis include critical thinking, active learning, coordination, social perceptiveness, monitoring, and complex problem solving. The importance of these cognitive and social skills should inform the design of skills training programs. These might be more important for younger workers who may not have received adequate on-the-job training opportunities. Unfortunately, despite strong demand for social and cognitive skills, post-secondary institutions are not prioritizing them or highlighting the fact that the importance of these skills remains underrated (Giammarco et al., 2021).

Policy Action 4: Foster a skills ecosystem that is based on a set of horizontal and vertical partnerships and that mainstreams green career considerations.

A successful labour force transition in a net-zero future is contingent on developing and sustaining an effective skills ecosystem, or institutional framework. These efforts can benefit from horizontal partnerships that already exist on the ground.[48] Given the breadth of job creation that is set to occur within a transition to net-zero emissions, the skills ecosystem would benefit from greater participation and engagement of federal and provincial environmental policy-makers and clean technology stakeholders like Environment and Climate Change Canada, Natural Resource Canada, and Environmental Careers Organization Canada (ECO Canada). These organizations can collaborate with provincial and regional skills development stakeholders to create the educational tools needed to equip workers with the skills they need for green

48 For instance, the Labour Market Information Council is working with Employment and Social Development Canada to create an occupational and skills taxonomy for Canada as well as crosswalks to allow researchers to apply U.S. skills data to Canada.

jobs in light of the net-zero emissions target. This sort of collaboration will be essential to ensuring that federal labour market policies, including immigration targets, are consistent with provincial efforts to support new workers and workers in transition. Vertical partnerships between the federal and provincial governments, provincial skills organizations, educational institutes, and other stakeholders within skills ecosystems will also be critical to supporting regional needs for upskilling and reskilling.

For Canada to successfully transition to a decarbonized future, irrespective of how its national decarbonization trajectory unfolds, it will be critical to accelerate the pace at which skills policies and initiatives are being developed. The skills needed for carbon-neutral jobs need to be introduced within national curricula as well as within national discussion around skills for the future. Recognizing that these skills include both technical skills and non-technical (cognitive and social) skills is also essential to ensuring that the focus of upskilling initiatives is dynamic and responsive and more focused on management, service orientation, collaboration, and problem solving.

Policy Action 5: Create mechanisms that support workers through a net-zero transition.

These mechanisms will help reduce the unemployment and underemployment created by the transition and help workers move successfully from high-carbon to low-carbon jobs. They could include a number of policy and programming options, such as extending financial support through Employment Insurance to ensure that it meets the evolving requirements of workers in transition; the provision of wage subsidies to firms to encourage them to hire workers who are transitioning; or the creation of "wage insurance" programs that help workers bridge the short-term financial disruptions that come with taking a new job and which might otherwise discourage them from accepting a new position. Other options also include investments that identify areas of high job growth at a regional or community level and connect employers with training organizations to accelerate upskilling and reskilling efforts. These policy and programming options will be especially helpful for workers in resource-dependent sectors in provinces like Alberta and Saskatchewan, who might face a harsher transition phase than others.

SECTION 8:
Potential Avenues for Future Research

While this report provides insights into the jobs and skills that will be important across different decarbonization scenarios, it also reveals several additional avenues along which further research ought to be advanced. Most importantly, the dataset created for this analysis can be sliced in several different ways to look at skills profiles and sectoral employment data. We suggest the following ideas to take this analysis forward:

- One way to categorize occupations is based on the level of education and training required. For example, so-called "skill level" A are professional jobs, B are technical jobs and skilled trades, C are intermediate jobs, and D are labour jobs. Building on the current analysis, it is possible to create score-based skills profiles for each of these skill levels. Doing so would enable a projection of the number of jobs in a decarbonized future that would be management, professional, technical, intermediate, or labour jobs and what their associated required skills profiles would be.
- A critical aspect missing in the national discussion around labour market dynamics for a green future is a consideration of the specific skills needs of equity-deserving workers (including women, Indigenous Peoples, persons with disabilities, racialized people, and 2SLGBTQ+ people) in a post-pandemic economic recovery. This analysis would support policy-makers and skills training institutes to develop transition plans that remove barriers to entry into the skilled trades and management positions for these groups, who have traditionally been underrepresented in the sectors studied in this report that are considered to be central to the net-zero transition.
- Another area of focus could be an in-depth analysis of the job outcomes across decarbonization pathways and associated skills needs in a specific province. For example, such an analysis could look at the variations in jobs emerging in British Columbia across sectors and scenarios. For sectors considered central to the net-zero transition in that province (alternative and renewable energy, energy efficiency, and green building), this study could include building a detailed and comprehensive skills profile for various categories of occupations to support skills development specific for British Columbia.
- Similarly, this type of analysis could be extended to focus on a particular

industry at the national level. For example, the variation in jobs emerging in the manufacturing sectors across lower-carbon-intensity and higher-carbon-intensity decarbonization pathways. This analysis could specifically drill down to the industry level to assess the important skills associated with automobile manufacturing, especially as investments in electric vehicle manufacturing ramp up.

- Finally, the analysis in this report does not provide a landscape analysis of the labour supply currently available across sectors and provinces or the labour shortages that might arise from decarbonization of the economy. Another area of future work could hone in on meeting future labour needs, the reskilling needs of current workers in transition, the skilling needs of new workers entering the labour force, or the removal of barriers to entry for such workers, especially women. Critically, workers' needs will depend on a variety of factors, including their socioeconomic and demographic characteristics and the region in which they live. Identifying the specific needs of specific workers will be essential to ensuring ready access to labour market information, effective designs for training and retraining policies, and transitional supports tailored to their needs and the needs of their communities. These supports could also include efforts designed to address the existing barriers and limitations associated with assessment and credentialing of workers' skills, which already represent significant obstacles to an optimally functioning labour market.

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Appendices

Appendix 1: The gTech Model

Navius' gTech model is well-suited to forecast the impact of a net-zero emissions future on employment in Canada:

> **It is a full economic model.** The gTech is a computable general equilibrium (CGE) model that represents transactions between all sectors of the economy as measured by Statistics Canada national accounts. Specifically, it captures all sector activity, all gross domestic product, all trade of goods and services, and the transactions that occur between households, firms, and government. As such, the model provides a forecast of how government policy affects many different economic indicators, including gross domestic product, investment, household income, and jobs. The model includes 95 sectors across all Canadian provinces, the territories (in aggregate), and the United States (in aggregate).

> **It is technologically explicit.** The gTech explicitly simulates how households and firms adopt technologies to meet their demand for energy services (e.g., transportation, heating, etc.). These choices are an important driver of energy consumption and emissions. Many of the technologies in the model are linked to commodities produced by the sectors in the model, and therefore technological change can change economic structure and employment. The gTech includes 300 different archetypal technologies that satisfy the demand for 70 end-uses (e.g., different technologies for light-duty vehicle travel, residential space heating, industrial process heat, etc.). The model manifests economic outcomes as a result of changing policy choices and cost profiles of different technologies that ultimately determine their uptake and production. As such, all of this activity is assumed to take place domestically with technology being manufactured and scaled across different sectors within the country. It is difficult to model clean technology imports due to the complexities around determining import tariffs on clean technology, as there is a lot of uncertainty around where they would be manufactured internationally. As well, the current Social Accounting Matrix (that is used to simulate the economy) does not explicitly account for clean technology sectors, particularly within the imports sector. This makes it challenging to differentiate between and simulate an imports sector that differentiates between clean technology and traditional commodities.

> **It is behaviourally realistic.** The technological choice is strongly influenced by behaviour. In some cases, behaviour has as much or more influence on a decision than financial costs (e.g., whether someone buys an electric vehicle). The gTech includes three behavioural dynamics designed to realistically describe how policies will influence technology choice: non-financial preferences, time preference for money, and market heterogeneity.

> **It simulates energy supply and energy markets, allowing it to show a transition of jobs from conventional energy sectors to emerging low-GHG energy sectors.** The gTech accounts for all major energy supply markets, such as electricity, refined petroleum products, and natural gas. Policy and technological change can increase the demand for low-carbon energy, including renewable electricity, hydrogen, and bioenergy, driving economic activity and employment in these sectors.

Representation of jobs in the gTech

The gTech is calibrated to labour statistics that are consistent with the system of national accounts from Statistics Canada. Employment by North American Industry Classification System (NAICS) code is mapped onto the sectors in gTech using 2015 figures. Employment changes in a model's projection as a function of how activity in each sector changes. For example, a sector that grows by a given amount will result in employment in that sector changing proportionally. Results for nascent sectors that did not exist in 2015, such as direct air capture or advanced biofuels manufacturing, are based on estimates of wages as a component of the total inputs to each of those sectors.

Employment can also change in a model's projection as a function of wage rates. If labour is in short supply, wage rates will rise and increase the supply of labour (i.e., gTech captures the economic decision to work). As well, the model operates with an assumption of structural unemployment. The magnitude of this structural unemployment is also affected by wage rates. It includes a simple relationship where higher wage rates reduce the structural unemployment in the forecast, and lower wage rates have the opposite impact.

The model has a few limitations concerning its ability to project employment. First, it is a long-term model that solves in five-year increments, and it does not show changes in employment related to business cycles (e.g., periods of recession versus periods of growth), so it will miss fluctuations in employment that are within the model time-step. Second, the model does not include the impact of inter-regional migration on employment, so it may exaggerate the differences in employment and wage rates between provinces if sectors grow and contract unevenly across Canada. Third, it assumes that there are no labour market barriers that prevent people from moving between jobs, so it may over-estimate increases and losses in jobs, as in reality, structural rigidities within the labour market slow the transition of workers across jobs. Fourth, the model assumes the same rate of labour productivity growth across all sectors when calculating jobs. Therefore, if productivity grows slower in a given sector, there will need to be more jobs for a given amount of economic activity (i.e., more jobs than we forecast). If productivity grows faster in each sector, there would be fewer jobs than we have forecast.

Appendix 2: Limitations of the Analysis

It is essential to recognize that this is a foresight exercise and not a forecasting exercise. Limitations pertaining to the gTech model include:

> Lack of skills datasets in Canada that link the National Occupation Classification with skills requirements and with industry classifications. The concordance table created by LMIC and ESDC was helpful in overcoming the first limitation, but even so, there were occupations for which mapping could not be done and their skills scores were not extracted.[49]

> The analysis is based on the 35 skills identified in the U.S. O*NET database. It is important to recognize the static nature of these skills. Changes in this database in the future that reflect changing importance and level scores for skills will change the outcomes of this analysis.

> Employment level data extracted from the LFS that acted as a bridge between the gTech model results (which are disaggregated by industry) and occupational skills were disaggregated at the NAICS industry groups level (four-digit). The gTech model results, however, were disaggregated at various levels.

> Relying on O*NET to match skills with occupations has potential drawbacks: 1) The skills classification in O*NET is made up of conceptual ideas and general descriptions. While they characterize important aspects of each occupation and rank them, they cannot convey other details which may be important to understand (e.g., on-the-job skills that employers look for when making hiring decisions); 2) O*NET does not have skill ratings for some occupations, and updates take time; 3) O*NET skills ratings reflect averages across occupations, regardless of geographic location, employing industry, or other unique features of a specific job.

> The gTech does not explicitly take the forecast of population growth into account. Rather, population growth is implicitly included in the GDP growth forecast used in the model, which itself is based on the Parliamentary Budget Office's (PBO) Fiscal Sustainability Report from 2020. This implicit inclusion

49 For more information on this concordance, refer to LMI Insight Report no. 35, September 2020: Job Skills Mapping: Building Concordance Between the US O*NET System and Canada's NOC, https://lmic-cimt.ca/publications-all/lmi-insight-report-no-35-job-skills-mapping-building-concordance-between-the-us-onet-system-and-canadas-noc/

of population growth projections means that any job projections generated by the gTech are likely to be understated. The PBO report is based on Statistics Canada's population projections. These projections include different scenarios—from high-growth to low-growth forecasts—depending on varying assumptions about fertility, mortality and immigration. The PBO report takes the medium forecast (M1) as the benchmark. This includes both slower population growth and an ageing population, compared to other more optimistic scenarios. This means that there will be fewer people in the labour force creating a downward pressure on labour force participation, leading to slower labour force growth projections. If the PBO report had taken a more optimistic population projection, their GDP forecasts would have been larger. Had this higher growth forecast been used as input in the gTech, it would have resulted in greater employment numbers. This is another reason that the job numbers modelled in this analysis are likely to be conservative estimates. Even though the analysis did not account for changing uncertainties pertaining to population forecasts, the impact of a larger population on jobs would not be greatly affected by climate policy. That is because economic growth can remain the same with fewer jobs and higher labour productivity without much interaction with climate policy. Hence, such population uncertainties are not expected to affect the differences in skills and employment, particularly as these differences are observed across scenarios. Highlighting the differences across these scenarios is one of the main purposes of this foresight exercise.

Appendix 3: Other Approaches to Skills Analysis

The Canadian Skills and Competencies Taxonomy developed by ESDC provides a start by streamlining terminology across several competency domains and concepts related to occupational work. However, it does not objectively link occupations with their skills profiles. Nonetheless, it does align with work activities to improve the comparability throughout occupations and sectors and future research may consider using the Taxonomy.

It should be noted that previous researchers have adopted different approaches to skills analysis, including both quantitative and qualitative approaches (Gregg et al., 2015). Quantitatively, the OECD (2012) estimated overall skills demand by calculating induced changes in the industry composition of employment (via the OECD's ENV-Linkages CGE model) caused by EU countries following different variations of the EU's emissions trading schemes.[50] Others have followed a qualitative demand-led approach. According to a report from the Government

50 Emission trading systems facilitate emission reductions where it is cheapest to achieve them. Polluters for whom it is costly to reduce their emissions are allowed to buy emissions allowances from polluters who can reduce them at lower costs (OECD, 2016) The EU follows the "cap-and-trade" system, where an upper limit on emissions is fixed, and emission permits are either auctioned or distributed for free according to specific criteria. The ENV-Linkages CGE model assumes three variations of emissions trading scheme: 1) Fragmented ETS, where all countries are reducing their own emissions through schemes without linking to others countries' action with fragmented carbon markets; 2) OECD-wide ETS, where OECD countries are allocated emission rights according to the same targets as in the fragmented scenario, but with trading options; and 3) Worldwide ETS, where all countries participate in a global carbon market with initial emission permits still allocated according to the Fragmented ETS case (OECD, 2012).

of the United Kingdom (HM Government, 2011), businesses in the United Kingdom partner with Skill Support Centres, National Skills Academies, and other organizations to identify and articulate the skills they need. Training institutions then design and supply the skills needed. In Canada, ECO Canada (2012) analyzed the texts of job vacancy advertisements (using computer-based algorithms) to identify and classify environmental skills and competencies across different categories that are required by potential employees.[51]

While each of these approaches to skills analysis is useful, there are certain drawbacks. The OECD (2012) skills analysis was based only on basic categories, such as whether workers have skills training or whether they are employed in a high-skill-level role. If jobs in these basic categories increased, it was assumed that the overall demand for skills increased. The United Kingdom's exercise was based on pre-existing and well-established institutional collaboration practices between businesses and skills assessment and training centers. Canada may lack this collaboration framework at present but could adopt this approach in the future if it were able to create the required collaborative underpinning. While ECO Canada (2012) developed skills categories based on technical and transferable competencies, these are not linked to industry data nor do they assign importance scores to these skills. The analysis in this report responds to these gaps by building a quantitative approach that considers the skills associated with potential decarbonization futures using 35 unique skills from the O*NET and their weighted importance scores using industry employment data.

51 ECO Canada developed these categories based on their own assessment and divided them into two broad competencies: 1) technical competencies, which show the ability to perform a task (i.e., a series of activities that together produce a measurable result) to the satisfaction of the employer or otherwise established norms; and 2) transferable competencies, behaviours or "soft skills" that may contribute to the successful performance of various technical tasks in the area of practice.

Appendix 4: Model Results: Net Job Changes Across Scenarios at the National Level (Relative to 2015; 000s)

Sector Description	% of Jobs in Model	2030			2040			2050		
		Electrons	Resources	Blended	Electrons	Resources	Blended	Electrons	Resources	Blended
Resources	2.7%	-58	-50	-47	-113	-76	-68	-111	-70	-61
Oil and Gas Extraction	0.2%	-5	0	2	-37	-8	0	-40	-9	-3
Oil and Gas Services	0.4%	-14	-8	-4	-37	-14	-5	-21	-3	3
Mining	0.4%	0	0	-1	3	2	-1	13	11	6
Agriculture	1.4%	-40	-43	-44	-52	-59	-64	-73	-76	-77
Utilities	0.5%	-7	-10	-9	7	-2	3	20	3	10
Electricity Generation	0.4%	-2	-3	-3	11	5	8	23	10	13
Electricity Distribution	0.1%	-2	-3	-3	2	-2	1	4	-1	3
Manufacturing	9.4%	130	103	87	292	198	157	477	409	332
Biofuels Production	0.03%	4	3	4	16	4	5	26	4	29
Hydrogen Production	0.01%	2	1	1	4	1	3	9	2	6
Metals	0.3%	-13	-13	-13	-14	-8	-15	-11	-7	-14
Paper	0.3%	3	3	2	7	7	-2	9	9	3
Non-Metallic Minerals	0.2%	-3	-2	-2	-1	0	-1	4	4	4
Chemicals	0.5%	0	1	-1	6	8	4	19	23	17
Other Manufacturing	8.1%	140	113	100	279	189	169	430	378	294
Transportation	4.1%	-6	-8	-5	14	4	20	92	85	83
Truck	1.3%	1	-1	-1	5	2	3	32	28	23
Other	2.0%	-15	-16	-14	-6	-10	0	35	30	27
Construction	7.2%	-33	-9	10	-70	-31	37	132	112	163
Services	76.0%	994	921	944	1,671	1,353	1,602	2,423	2,340	2,386
Direct Air Capture	0.1%	0	0	0	0	32	10	69	147	75
Total	**100%**	**1,020**	**948**	**981**	**1,802**	**1,479**	**1,761**	**3,101**	**3,026**	**2,988**

Note: The table shows absolute changes in jobs in each scenario in 2030, 2040, and 2050 relative to 2015. In Table 5 (see page 40) in the report, jobs are reported as full-time equivalents, which are total jobs corrected to full-time equivalents.

Electrons: Lower-carbon-intensity carbon pathway with carbon price rising to $170/Mt in 2030 (nominal CAD), adjusted for inflation thereafter, emissions cap and more fuel switching and renewables, lower CCUS (due to higher costs), less activity in fossil fuel sectors (due to lower oil prices, 30–40 real USD/bbl long-run). Resources: higher-carbon-intensity carbon pathway with less fuel switching and renewables, more CCUS (due to lower costs), more activity in fossil fuel sectors (due to higher oil prices, 80–90 real USD/bbl long-run). Blended: a middle ground between first and second scenarios.

Appendix 5: Model Results: Net Job Changes Across Scenarios in Select Provinces (Relative to 2015; 000s)

Ontario										
Sector Description	% of Jobs in Model	2030			2040			2050		
		Electrons	Resources	Blended	Electrons	Resources	Blended	Electrons	Resources	Blended
Resources	1.3%	-17	-17	-17	-21	-22	-23	-24	-25	-25
Oil and Gas Extraction	0.0%	0	0	0	0	0	0	0	0	0
Oil and Gas Services	0.0%	0	0	0	0	0	0	0	0	0
Mining	0.2%	-2	-2	-2	-2	-2	-3	-1	0	-2
Agriculture	1.0%	-15	-15	-15	-20	-21	-21	-25	-26	-25
Utilities	0.6%	-6	-7	-6	2	-2	1	9	1	4
Electricity Generation	0.4%	-3	-4	-4	3	1	2	10	3	5
Electricity Distribution	0.1%	-1	-1	-1	1	-1	1	2	0	2
Manufacturing	10.9%	42	34	29	52	44	38	144	144	101
Biofuels Production	0.02%	1	1	1	1	1	1	5	1	5
Hydrogen Production	0.01%	0	0	0	1	0	1	3	1	2
Metals	0.1%	-1	-1	-1	1	-1	1	2	0	2
Paper	0.2%	0	0	0	2	2	0	4	4	3
Non-Metallic Minerals	0.2%	-1	-1	-1	0	0	0	2	2	1
Chemicals	0.6%	1	2	1	1	2	2	4	10	6
Other Manufacturing	9.5%	51	43	38	56	41	42	134	131	93
Transportation	4.4%	7	6	7	10	7	14	40	37	34
Truck	1.6%	4	4	4	4	4	5	16	16	12
Other	2.0%	-2	-2	-2	2	-1	4	16	15	13
Construction	6.6%	10	7	9	14	3	25	55	50	42
Services	76.2%	391	378	385	568	489	575	813	826	826
Direct Air Capture	0.0%	0	0	0	0	0	0	0	0	0
Total	**100%**	**427**	**402**	**406**	**625**	**519**	**629**	**1,037**	**1,034**	**982**

Model Results: Net Job Changes Across Scenarios in Select Provinces (Relative to 2015; 000s) (continued)

Quebec										
Sector Description	% of Jobs in Model	2030			2040			2050		
		Electrons	Resources	Blended	Electrons	Resources	Blended	Electrons	Resources	Blended
Resources	2.0%	-9	-9	-9	-11	-14	-14	-12	-15	-13
Oil and Gas Extraction	0.0%	0	0	0	0	0	0	0	0	0
Oil and Gas Services	0.0%	0	0	0	0	0	0	0	0	0
Mining	0.4%	0	0	0	-1	-1	-1	0	1	0
Agriculture	1.2%	-9	-9	-9	-13	-13	-13	-15	-16	-15
Utilities	0.6%	-3	-3	-3	-4	-4	-4	-5	-6	-5
Electricity Generation	0.4%	-2	-2	-2	-3	-3	-3	-4	-4	-4
Electricity Distribution	0.1%	-1	-1	-1	0	-1	0	0	-1	0
Manufacturing	11.3%	22	18	18	45	34	31	102	84	70
Biofuels Production	0.04%	1	1	1	3	1	1	6	1	7
Hydrogen Production	0.03%	1	1	1	1	1	1	0	1	1
Metals	0.1%	-1	-1	-1	0	-1	0	0	-1	0
Paper	0.4%	2	1	1	4	3	1	5	5	3
Non-Metallic Minerals	0.3%	-1	-1	-1	0	-1	-1	0	0	0
Chemicals	0.5%	1	0	0	1	2	1	4	5	4
Other Manufacturing	9.5%	22	18	18	43	31	33	91	75	61
Transportation	3.8%	-3	-6	-5	0	-6	-3	10	3	3
Truck	1.3%	0	-1	-1	1	-1	-1	6	3	3
Other	2.0%	-4	-6	-5	-4	-7	-4	-1	-2	-3
Construction	6.1%	-4	-8	-7	4	-10	0	3	1	2
Services	76.2%	107	88	97	180	99	167	221	179	215
Direct Air Capture	0.0%	0	0	0	0	0	0	0	0	0
Total	**100%**	**110**	**80**	**91**	**214**	**99**	**177**	**318**	**246**	**271**

Model Results: Net Job Changes Across Scenarios in Select Provinces (Relative to 2015; 000s) (continued)

Alberta										
Sector Description	% of Jobs in Model	2030			2040			2050		
		Electrons	Resources	Blended	Electrons	Resources	Blended	Electrons	Resources	Blended
Resources	5.3%	-19	-9	-5	-69	-23	-11	-64	-18	-7
Oil and Gas Extraction	10.2%	-47	-30	-22	-128	-54	-32	-117	-36	-20
Oil and Gas Services	2.1%	-11	-5	-1	-32	-10	-2	-18	0	5
Mining	0.3%	-3	-3	-3	-2	-2	-2	-1	-1	-1
Agriculture	1.4%	-3	-4	-5	-2	-6	-8	-9	-10	-11
Utilities	0.2%	1	0	0	5	3	5	10	5	6
Electricity Generation	0.1%	1	1	1	5	3	4	8	5	5
Electricity Distribution	0.1%	0	0	0	1	0	0	2	0	1
Manufacturing	7.4%	34	24	16	130	69	46	122	92	78
Biofuels Production	0.04%	1	1	1	4	1	1	4	1	4
Hydrogen Production	0.09%	0	0	0	1	0	1	2	0	1
Metals	0.1%	-1	-1	-1	-1	-1	-1	-2	-1	-2
Paper	0.3%	0	0	0	3	1	-1	2	1	0
Non-Metallic Minerals	0.2%	0	0	0	0	0	0	1	1	1
Chemicals	0.6%	-2	-1	-2	2	2	0	8	6	6
Other Manufacturing	6.0%	37	26	19	124	66	49	109	86	69
Transportation	3.3%	-5	-1	1	0	5	8	17	23	24
Truck	1.0%	-1	-1	-1	1	1	1	6	6	5
Other	1.5%	-3	-1	1	-2	2	4	11	11	12
Construction	10.1%	-26	-1	9	-67	-11	9	63	37	73
Services	73.3%	299	282	281	581	524	549	884	881	875
Direct Air Capture	0.4%	0	0	0	0	21	9	64	125	65
Total	**100%**	**284**	**294**	**302**	**581**	**586**	**615**	**1,095**	**1,144**	**1,115**

Model Results: Net Job Changes Across Scenarios in Select Provinces (Relative to 2015; 000s) (continued)

British Columbia										
Sector Description	% of Jobs in Model	2030			2040			2050		
		Electrons	Resources	Blended	Electrons	Resources	Blended	Electrons	Resources	Blended
Resources	2.7%	2	2	2	6	4	3	7	8	7
Oil and Gas Services	0.1%	0	0	0	0	0	0	0	0	0
Mining	0.6%	2	2	2	2	3	2	2	4	2
Agriculture	1.4%	-2	-3	-3	-2	-3	-4	-3	-3	-4
Utilities	0.5%	1	1	1	2	2	2	3	3	4
Electricity Generation	0.4%	2	2	2	3	3	3	4	4	4
Electricity Distribution	0.1%	0	0	0	0	0	0	1	0	1
Manufacturing	6.6%	25	23	22	42	38	33	69	59	56
Biofuels Production	0.02%	0	0	0	1	0	0	2	0	4
Hydrogen Production	0.01%	0	0	0	0	0	0	0	0	0
Metals	0.1%	0	0	0	0	0	0	0	0	0
Paper	0.5%	1	1	0	-1	-1	-3	-3	-2	-4
Non-Metallic Minerals	0.2%	0	0	0	0	1	0	1	1	2
Chemicals	0.1%	0	0	0	1	1	1	1	1	1
Other Manufacturing	5.6%	22	21	20	41	37	34	66	58	52
Transportation	4.6%	2	1	2	10	8	10	22	23	24
Truck	0.7%	0	0	0	2	1	1	5	4	4
Other	2.6%	-1	-2	-2	3	1	2	9	9	9
Construction	8.0%	14	15	18	13	17	23	38	45	58
Services	77.5%	230	215	220	378	326	362	529	499	509
Direct Air Capture	0.0%	0	0	0	0	6	0	2	13	5
Total	**100%**	**275**	**257**	**265**	**452**	**401**	**433**	**670**	**651**	**663**

Appendix 6: Net Job Losses and Skills Scores for Workers in Sectors Across Decarbonization Scenarios

Sector Name	Net Jobs in 2050, Relative to 2015			Basic Process Skills			Social Skills					PS	Technical Skills				Systems Skills		Management Skills	
	SC1	SC2	SC2	CT	AL	MO	SP	CO	PA	IN	SO		OM	OC	TS	QC	JD	SA	TM	PM
Farming	-31	-42	-31	59	45	57	50	54	42	41	39	47	49	47	35	43	53	34	51	47
Animal Production & Aquaculture	-41	-41	-45	63	49	60	51	56	46	45	41	52	52	48	37	46	58	41	54	51
Agriculture Services	-6	-6	-6	55	43	54	46	50	38	39	39	47	50	50	35	40	51	36	47	40
Oil & Gas Extraction	-47	-10	-3	58	47	52	45	48	40	41	39	51	43	36	32	38	51	40	47	40
Coal Mining	-8	-4	-7	51	39	46	40	44	31	36	34	44	49	48	42	41	44	30	42	34
Oil & Gas Services	-26	-4	3	57	45	53	45	49	39	41	38	48	48	43	36	40	49	35	46	42
Electricity Generation & Distribution*	-23	-24	-23	60	49	53	47	49	41	42	44	53	42	31	34	39	52	43	50	41
Natural Gas Distribution	-7	-6	-7	44	35	40	36	37	31	29	33	38	27	19	19	26	38	30	38	30
Manufacturing	-39	-25	-37	54	42	52	46	46	37	37	37	47	45	38	32	42	48	36	48	36
Petroleum & Coal Products	-13	-7	-11	61	48	56	47	50	39	42	40	52	52	44	38	45	53	42	50	41
Iron & Steel Mills	-15	-15	-15	55	42	53	47	49	36	37	36	47	49	43	36	44	49	35	49	38

* These are electricity subsectors that lose jobs across the decarbonization scenarios, not to be confused with other electricity subsectors that gain jobs in Table 5 (see page 40) in the report.

Note: Skill scores range from 0 to 100 and are weighted based on the 2019 employment from the LFS for each sector represented in this table. Due to the size of this table, the headers are abbreviated according to the legend below. The numbers highlighted in purple are the greatest net job losses.

Legend:

SC1: Scenario 1 (Electrons); SC2: Scenario 2 (Resources); SC3: Scenario 3 (Blended).

CT: Critical thinking; AL: Active learning; MO: Monitoring; SP: Social perceptiveness; CO: Coordination; PA: Persuasion; IN: Instructing; SO: Service orientation; PS: Complex problem solving; OM: Operations monitoring; OC: Operations control; TS: Troubleshooting; QC: Quality control; JD: Judgement & decision making; SA: Systems analysis; Time management; PM: People management

Appendix 7: O*NET Skill Classification

This section is adapted from the report, O*NET Analyst Occupational Skill Ratings: Procedures, by Tsacoumis & Willison (2010), which compiles skill level and importance ratings for the 35 skills 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. Overall, these 35 skills are grouped into seven categories as outlined in the table 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	• **Reading Comprehension:** Understanding written sentences and paragraphs in work-related documents. • **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. • **Writing:** Communicating effectively in writing as appropriate for the needs of the audience. • **Speaking:** Talking to others to convey information effectively. • **Mathematics:** Using mathematics to solve problems. • **Science:** Using scientific rules and methods to solve problems.
Process: Procedures that contribute to the more rapid acquisition of knowledge and skill across a variety of domains	• **Critical Thinking:** Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions, or approaches to problems. • **Active Learning:** Understanding the implications of new information for both current and future problem solving and decision-making. • **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	Skills Details
Social Skills: Developed capacities used to work with people to achieve goals	• **Social Perceptiveness:** Being aware of others' reactions and understanding why they react as they do. • **Coordination:** Adjusting actions in relation to others' actions. • **Persuasion:** Persuading others to change their minds or behaviour. • **Negotiation:** Bringing others together and trying to reconcile differences. • **Instructing:** Teaching others how to do something. • **Service Orientation:** Actively looking for ways to help people.
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.
Technical Skills: Developed capacities used to design, set up, operate, and correct malfunctions involving the application of machines or technological systems	• **Operations Analysis:** Analyzing needs and product requirements to create a design. • **Technology Design:** Generating or adapting equipment and technology to serve user needs. • **Equipment Selection:** Determining the kind of tools and equipment needed to do a job. • **Installation:** Installing equipment, machines, wiring, or programs to meet specifications. • **Programming:** Writing computer programs for various purposes. • **Operations Monitoring:** Watching gauges, dials, or other indicators to make sure a machine is working properly. • **Operation and Control:** Controlling operations of equipment or systems. • **Equipment Maintenance:** Performing routine maintenance on equipment and determining when and what kind of maintenance is needed. • **Troubleshooting:** Determining causes of operating errors and deciding what to do about it • **Repairing:** Repairing machines or systems using the needed tools. • **Quality Control Analysis:** Conducting tests and inspections of products, services, or processes to evaluate quality or performance.

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.
Resource Management Skills: Developed capacities used to allocate resources efficiently	• **Time Management:** Managing one's own time and the time of others. • **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.

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