



Decarbonization and its Impact on Manufacturing

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About Future Ready

The Future Ready program is a \$19 million program funded in part by Employment and Social Development Canada's Sectoral Workforce Solutions Program to support companies in onboarding new and diverse workers to Canadian manufacturing. The initiative will also aid Canadian manufacturers in identifying their critical skills gaps to support the future profitability and growth of their organization through NGen's highly regarded Transformation Leadership Program. Through these approaches, the program aims to provide demand-driven solutions for the manufacturing sector, one of the sectors hardest hit by the pandemic, and a key to the recovery of the Canadian economy.



About CSTEC

CSTEC is an enabler of innovative, multi-stakeholder solutions to training related problems faced by employers and unions within the broader manufacturing, mining and forestry sectors. The organization focuses on a broad range of training issues related to workplace and essential skills training, apprenticeship and technical training, needs assessments, occupational standards, labour market information, labour adjustment and career enhancement for young people and the unemployed.



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Introduction

Over the past years, Canada has strengthened its commitment to reduce greenhouse gas emissions and transition to a low-carbon economy. The country's decarbonization efforts, which include the reduction and gradual elimination of carbon emissions from various sources, aim to meet Canada's international commitments under the Paris Agreement. Outlined in its 2030 Emissions Reduction Plan, Canada plans on reducing emissions by 40% to 45% below 2005 levels by 2030, and achieve net-zero emissions by 2050¹. To support these efforts, sectors such as energy production, transportation, building, and manufacturing are currently undergoing changes to their operations to reduce or eliminate their carbon footprint. Among those sectors, manufacturing is a significant contributor to carbon emissions. Globally, the sector is responsible for around 20% of the world's carbon emissions². In Canada, manufacturing contributed around 13.8% of the nation's 738 mega tonnes of carbon dioxide equivalent (MT CO₂ eq.) in 2019³. Decarbonizing operations in manufacturing, simultaneous with similar efforts in other carbon-intensive sectors, is essential for achieving the outlined climate targets.

While decarbonization efforts may generate new opportunities in green and clean technologies in manufacturing, for existing carbon-intensive manufacturing businesses, decarbonization may carry significant costs

and challenges, including the need to invest in new technologies and infrastructure, restructure supply chains, and adapt to new regulations and policies.

There are numerous strategies for decarbonizing operations in the manufacturing sector. Decarbonization efforts can address the emissions of manufacturing processes, or products (or both at the same time), and focus on reducing them. Process decarbonization may involve implementing production methods which are less energy-intensive and reduce the reliance on fossil fuels in manufacturing. Manufacturers can also invest in innovative production technologies which optimize procedures and reduce material waste. Other initiatives focusing on product decarbonization are comprised of steps such as using low-carbon materials to reduce the emissions associated with final products, increasing the use of recycled materials, and most significantly, manufacturing products with technologies that generate fewer emissions. While both process and product approaches to decarbonization carry opportunities for innovation and modernization in manufacturing, particularly for companies that can develop low-carbon production technologies and products, decarbonization may also entail changes to the way manufacturers operate, with potential implications to cost, supply chains, competition, and the workforce. In some cases, decarbonization may lead to the



phasing out of certain processes, products, components or parts, which may hold significant implications on industries and businesses.

As it relates to the manufacturing workforce, technological changes associated with decarbonization efforts may introduce changes to manufacturing jobs, their roles and requirements. Upskilling may be required to assist workers in adapting to the changes in processes or products. Entrants to the workforce may need to learn new skills to operate newly introduced products, equipment and systems. This paves the way to “green jobs” in manufacturing in which workers directly or indirectly contribute to environmental sustainability and promote a low-carbon economy through implementing, operating, and producing technologies with low carbon footprint. Green jobs may entail traditional jobs in manufacturing such as engineering, research, skilled trades and production jobs in industries which are transitioning, or already have transitioned to sustainable process and products in manufacturing. Green jobs may also include newly introduced roles in the future which contribute to the transition to the green economy in manufacturing.

Decarbonization in manufacturing can also lead to job losses, especially when products,

components or parts are eliminated or replaced by less carbon-intensive ones, leading to alterations in supply chains. In such cases, workers may need to transition to new careers and apply their skills in other industries.

This report explores the impact that decarbonization will have on Canada’s manufacturing sector and its workforce. To understand these implications, it is important to identify the manufacturing industries and sub-industries which currently are, or will be decarbonizing their operations in the future as part of their efforts to reduce their carbon footprint. This report first provides a brief overview of the international efforts and national policies on decarbonizing the economy. The report then highlights five manufacturing industries in which decarbonization efforts are either fully or partially underway, and how this transition is introducing changes to their operations and products. Finally, the report highlights a list of 41 manufacturing sub-industries within Canada’s manufacturing sector which are challenged in transitioning to the decarbonized economy. This analysis is supplemented with details on employment in manufacturing, as well as the number of businesses in the sector.



International Efforts and Government Policy

Over the past several decades, it has become clear that in order to slow the impacts of climate change there needs to be a focus on reducing greenhouse gas (GHG) emissions globally. Since withdrawing from the Kyoto Protocol in 2012, Canada has recommitted to taking part in international efforts to reduce GHG emissions by signing the Paris Agreement (2015). The Paris Agreement specified the goal of limiting global warming to significantly below 2°C, preferably 1.5°C above pre-industrial levels⁴. In 2021, the Canadian Government established a legally binding process to meet the criteria of the Paris Agreement through the Canadian Net-Zero Emissions Accountability Act⁵. This Act outlines what each five-year national emissions-reduction plan must contain.

In 2016, Canada released the Pan-Canadian Framework on Clean Growth and Climate Change outlining a plan to foster economic growth while reducing GHG emissions⁶. The overarching goal of the framework is to meet or exceed Canada's 2030 target of reducing GHG emissions by 30% below 2005 levels. To meet this goal, provinces and territories can design their own programs and policies which the federal government will support through investments in infrastructure, specific emission-reduction targets and clean technologies.

Canada's strengthened climate plan in 2020 addressed how the disruption of the pandemic could be an opportunity to build

back a thriving low carbon economy⁷. The plan, A Healthy Environment and a Healthy Economy, reiterated the need for federal, provincial, and regional governments to work with businesses and communities to achieve GHG emission goals and environmentally clean economic growth. The plan introduced 64 strengthened and new federal policies, programs and investments which includes improving energy efficiency, making electric vehicles (EVs) more accessible and affordable, developing Canada's battery manufacturing supply chain, and working with automotive and aerospace manufacturers to ramp up zero-emissions transportation products production and investments. The plan emphasizes that focus will remain on the workers and communities impacted by these shifts in order to ensure that the benefits are widespread.

Canada's most recent plan (2022), Net-Zero Emissions by 2050, aims for the economy to produce no GHG emissions and offset the GHG it does produce⁸. Building off the Pan-Canadian Framework and Canada's strengthened climate plan, the 2030 Emissions Reduction Plan introduces a Net-Zero Accelerator (NZA) Fund which will provide up to \$8 billion to support large-scale emitters in key industrial sectors to dramatically reduce their domestic GHG emissions⁹. The Net-Zero Challenge provides a path for Canadian businesses to get involved in transitioning their operations and facilities to net-zero by 2050. The initiative is



voluntary and is the starting point for the collaboration and exchange of plans and best practices amongst participants¹⁰.

Finally, in 2023, Natural Resources Canada launched the Green Industrial Facilities and Manufacturing Program (GIFMP) to provide financial assistance of up to \$20 million per proposal for industrial facilities and

manufacturing to maximize energy efficiency and reduce emissions¹¹. The program will support activities such as energy assessments and audits, training for energy management practitioners, and capital investments in energy systems and infrastructure upgrades for manufacturers and other industrial businesses.





Decarbonization in Manufacturing

Various industries within the manufacturing sector have been actively implementing strategies to reduce their greenhouse gas (GHG) emissions and transition towards more sustainable products and practices.

While government policy and regulation have been key drivers of decarbonization efforts, technological advancement, as well as corporate strategy recognizing the need to transition to clean technologies and minimize carbon footprint have also been key in accelerating these initiatives. While many of these efforts in manufacturing are already underway, progress on decarbonizing operations and reducing emissions varies among industries of manufacturing. This section provides an overview of five notable manufacturing industries which are currently undergoing changes to decarbonize their products, processes, or both at the same time.

Automotive Manufacturing Industry

The automotive industry has been at the forefront of decarbonization efforts, specifically in product decarbonization. Driven largely by advancements and innovation in automotive and battery technology, the automotive manufacturing industry has been gradually shifting from the production of internal combustion engine vehicles (ICEVs), which heavily rely on fossil fuels to operate, to electric vehicles (EVs) manufacturing. Global automotive manufacturers, along with chemical

manufacturing and battery technology companies have been heavily investing in EV battery research and development, as well as EV battery production. These efforts have been supplemented by incentives from government to support EV research and manufacturing, and accompanied with policies on sales targets of EVs. On average, hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) emit up to 60% less emissions compared to ICEVs, while battery electric vehicles (BEVs) reduce emissions by up to 80%¹². Over the upcoming years, the share of EVs in the automotive market is expected to grow leading to a significant reduction in the carbon footprint of the industry.

Steel Manufacturing Industry

The steel manufacturing industry is another major source of GHG emissions in which process decarbonization is key in transitioning the industry to sustainable practices. Besides the energy-intensive nature of iron and steel production in coke ovens, the process of steel manufacturing involves the use of carbon-intensive raw materials such as coal which also release emissions (carbon dioxide (CO₂) and carbon monoxide (CO)) as by-products in production. To reduce the emissions of steel production, companies have been investing in the development and implementation of more energy-efficient production technologies such as electric arc furnaces and hydrogen-



based steelmaking methods, as well as the use of scrap metal in production¹³. While coke ovens are still needed in the smelting process of iron ore, electric arc furnaces are an alternative that uses scrap metal in the production processes. This technology has been significantly lowering the carbon footprint of the steel manufacturing industry.

Mining and oil and gas machinery manufacturing industry

The mining and oil and gas machinery manufacturing industries will be significantly impacted by decarbonization efforts, especially as industries shift towards alternative sustainable energy sources such as wind turbines, solar panels, and energy storage systems including EV batteries. This industry will be mainly affected by the transition away from fossil fuels like coal, and because of lower demand for oil and gas field machinery. The shift in demand, governmental regulatory pressure, as well as the shift in industrial investment towards projects that align with a low-carbon future, will have direct implications on the oil and gas sector and consequently, the mining and oil and gas machinery manufacturing industry. Alternatively, the mining and oil and gas machinery manufacturing industry can play a key role in developing technologies which not only reduce emissions from the production of fossil fuels, but also assist in the mining and extraction of critical minerals, such as lithium, cobalt, and rare earth elements. These elements and minerals are critical in clean energy technologies, especially in batteries and wind turbines.

Cement and Concrete Manufacturing Industry

The cement and concrete manufacturing industry is among the most carbon-intensive industries in manufacturing. This is due to the high levels of carbon emissions generated by production processes that are energy-intensive, and the raw materials used in cement production. During production, the raw materials of cement are subjected to temperatures exceeding 1,000°C in a process known as “clinker production”. Throughout this process, fuels used in heating emit carbon dioxide (CO₂) and other greenhouse gas (GHG) emissions upon combustion. Furthermore, during this heating process, limestone, a core ingredient in cement, releases significant amounts of CO₂ as it turns into calcium oxide (CaO).

Cement manufacturing is among more the challenging industries to decarbonize. Several methods are currently under development in order to reduce the carbon footprint of cement production. These methods include clinker material substitution with fly ash and granulated slag, the introduction of new heating and combustion technologies in clinker production, and the use of alternative fuels in manufacturing¹⁴. Despite these efforts to decarbonize, these new procedures and technologies might not be scalable for years, making the decarbonization of the cement manufacturing industry far behind other manufacturing industries.



Aerospace Manufacturing Industry

The aerospace industry, particularly aviation, is responsible for around 2.5% of global CO₂ emissions and approximately 12% of the CO₂ emissions of the transportation industry (ICAO, 2021). In addition to CO₂, the combustion process in an aircraft's engine also releases other GHGs including nitrogen oxide, sulfate aerosols, and other carbon particles. To reduce the carbon footprint of aviation, the industry has been working on incremental improvements to current aviation technologies, as well as on the development of innovative solutions and technologies to reduce or eliminate the emissions of aircrafts. Besides improving fuel and engine efficiency, multiple aviation companies have been exploring and developing electric and hybrid propulsion systems for aircrafts including electric aviation propulsion systems, batteries, as well as a hydrogen fuel cells as a power source for aircrafts. Despite the initiatives of leading companies in this space such as Airbus, Boeing, and Rolls Royce, the deployment of such technologies in commercial aircrafts is many years away^{15, 16}.

Besides these five industries, numerous other industries and sub-industries in manufacturing may ultimately decarbonize, although the process of decarbonization may not be as impactful to processes and products as in the examples mentioned above. Some manufacturing industries may follow more traditional methods of reducing their carbon footprint through using recycled raw materials, implementing carbon capture technologies, and relying on renewable energy sources. For example, the textile industry may use recycled fibers, while the paper and pulp industry may rely on

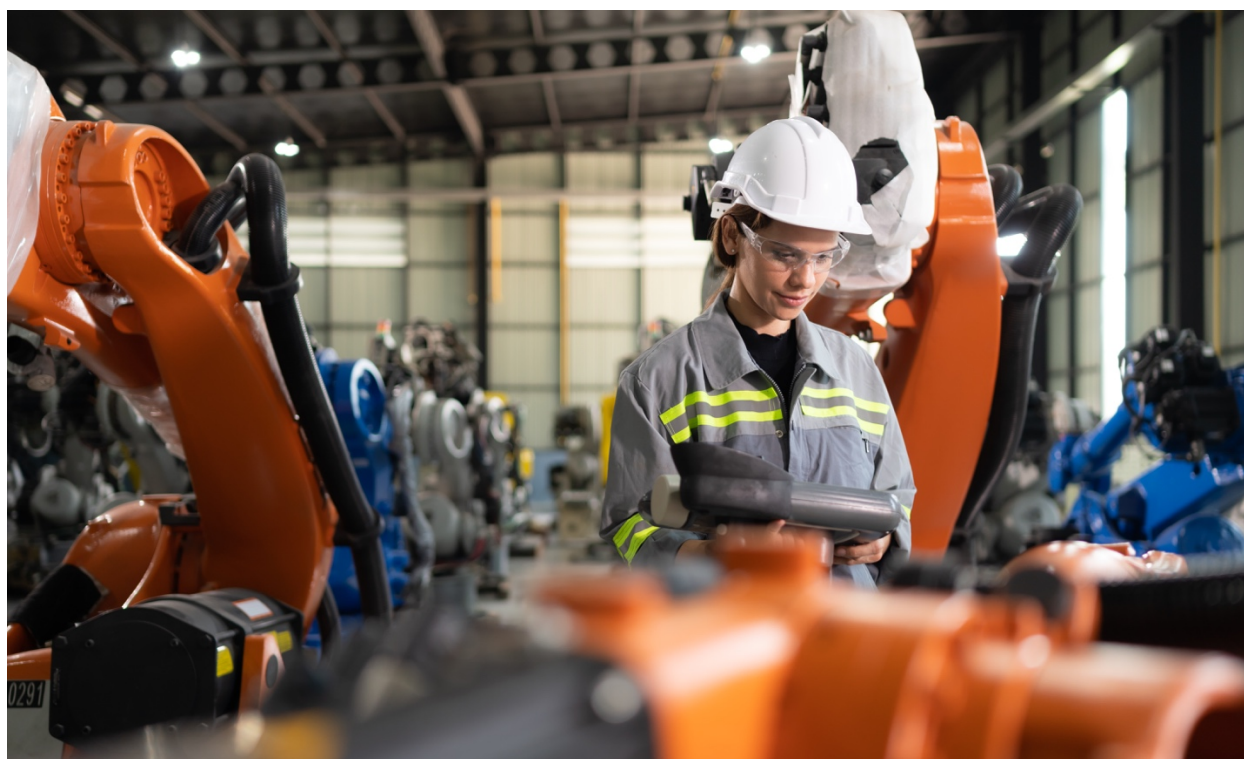
renewable energy sources such as biomass. These industries may not require significant changes in their processes or products but may need to adopt more sustainable practices and invest in renewable energy sources to meet decarbonization goals. In addition, some manufacturing industries may adopt more circular business models to reduce waste and emissions. Therefore, the degree of decarbonization may vary across the industries and sub-industries of manufacturing.

The implications of the transition to a low-carbon economy on the labour force will also vary among the industries and sub-industries of manufacturing. For some of the manufacturing industries which may not require significant changes in their processes or products to meet decarbonization goals, the implications on workers and their skills may be minimal. However, for the industries which will need to adopt new production technologies or manufacture fundamentally altered products, the consequences on workers and their skills may be more substantial. These implications may entail changes in the skills and training needed by the workforce, and may lead to potential job losses in certain areas of industry. For example, workers in automotive manufacturing roles such as vehicle assemblers or machine operators may need to learn new skills such as operating and monitoring advanced vehicle and battery production technologies, as well as handling and assembling new components and parts of EVs. In some areas of the automotive parts manufacturing industry, the transition away from internal combustion engines (ICE) may directly translate to job losses, especially for



workers manufacturing ICE-specific parts and components such as exhausts and engine pistons¹⁷. Similar implications are expected for workers in industries that manufacture products that are heavily reliant on fossil fuels, especially as the demand for these products declines.

The transition to a low-carbon economy will also create new job opportunities in other emerging manufacturing industries such as renewable energy equipment production and energy storage systems manufacturing. These jobs may require slightly different skills and education levels than jobs in traditional manufacturing industries.





Assessing the Impact of Decarbonization On Canadian Manufacturing

The challenges and implications of decarbonization in Canada's manufacturing sector will not be uniform across all its industries and sub-industries. Assessing and determining the challenges and impacts of decarbonization on Canada's manufacturing sector and its labour force is complex, and entails an in-depth analysis of individual industries and sub-industries. This requires a comprehensive approach that considers the specifics of each manufacturing industry and sub-industry, as well as the broader context of policy, economics, and labour. In practice, detailed analysis could be done even at the plant level.

It is possible, however, to identify broad trends and potential challenges across the manufacturing sector. Industries and sub-industries can be categorized based on their environmental impact, as well as on the challenges they face in transitioning to decarbonized operations. This analysis can be considered a *preliminary assessment*, and can be supplemented with more detailed impact assessments on individual industries, sub-industries, businesses and jobs in manufacturing.

To analyze the impact of decarbonization on Canada's manufacturing sector, we refer to the North American Industry Classification System (NAICS) codes to identify and categorize the industries and sub-industries

within the manufacturing sector. The NAICS provides a standardized way of classifying businesses and industries based on their economic activity, making it a useful tool for analyzing trends and challenges within specific industries. The NAICS also offers multiple levels of detail in industrial classification, with comprehensive information on the list of products and services offered by each sub-industry at the highest level of detail¹⁸.

Under the 2022 NAICS, manufacturing activities are defined under codes 31 - 33 at the 2-digit detail level. The 3-digit detail level of NAICS offers a comprehensive list of 21 manufacturing industries which are presented in table 1. Table 1 also presents the emissions of each manufacturing industry (in Mt CO₂ eq.), along with the emissions intensity and product emissions level of each industry. While Canada's National Pollutant Release Inventory (NPRI) database provides the total emissions of each industry with a high level of confidence, estimating or calculating the emissions from products with a high level of accuracy can be more challenging. As a result, the emissions from the products of each manufacturing industry were categorized into groups of low, moderate, and high, reflecting the varying degrees of emissions associated with different types of products.



As demonstrated in table 1, the manufacturing industry with the highest emissions in Canada is the primary metal manufacturing industry, followed by the chemical manufacturing industry, the petroleum and coal manufacturing industry, and the non-metallic mineral product manufacturing industry. Combined, these four manufacturing industries contribute to more than 85% of Canada's total manufacturing emissions. Additionally, these four industries exhibit the highest emissions intensity, with the non-metallic mineral product manufacturing industry being the highest emission intensive industry at 0.71 kt CO₂ per million dollars of industry output, followed by the primary metal manufacturing at 0.37 kt CO₂ per million dollars of industry output.

As for product emissions, the emissions of petroleum and coal, as well as transportation equipment in Canada exceed 100 Mt CO₂ eq. This is followed by industries with moderate product emissions such as chemical manufacturing, machinery manufacturing, and electrical equipment, appliance and component manufacturing. The emissions of the products of these industries range between 1 Mt CO₂ eq. and 100 Mt CO₂ eq.

On the 6-digit level, the NAICS system provides a list of 248 manufacturing sub-

industries along with a list of illustrative examples of the products, processes, and activities of each sub-industry. This level of detail allows for a more granular analysis of the impact of decarbonization on each manufacturing sub-industry, as well as its processes and products.

Using the 2022 NAICS, a dataset of the 248 manufacturing sub-industries is compiled, along with a list of more than 9,250 illustrative examples of products, processes, and activities under these sub-industries. To identify the highest emitting sub-industries, products and processes in manufacturing, both the National Pollutant Release Inventory (NPRI) and the Greenhouse Gas Inventory databases are used to estimate the process and product emissions of each of the 248 manufacturing sub-industries¹⁹. To further establish the implications of decarbonization on manufacturing businesses and the associated labour force, the dataset is coupled with information on the number of businesses, as well as the number of employees within each sub-industry. The data on the number of businesses is retrieved from the 2021 Canadian Business Counts database, whereas the data on the number of employees is obtained from the 2021 Annual Survey of Manufacturing and Logging Industries^{20, 21}.



Table 1. List of 3-digit detail level manufacturing NAICS-defined industries with their respective total emissions, emissions intensity, as well as the level of emissions from products.

Industry	Process		Product
	Total Emissions (Mt CO ₂ eq.)*	Emissions Intensity (kt CO ₂ eq. per \$ million output)**	Product Emissions***
Food Manufacturing	2,525	0.0184	Low
Beverage & tobacco product manufacturing	284	0.0143	Low
Textile mills	10	<0.01	Low
Textile product mills	<10	<0.01	Low
Clothing manufacturing	<10	<0.01	Low
Leather & allied product manufacturing	<10	<0.01	Low
Wood product manufacturing	693	<0.01	Low
Paper manufacturing	5,921	0.0125	Low
Printing & related support activities	<10	<0.01	Low
Petroleum & coal product manufacturing	17,561	0.2251	High
Chemical manufacturing	19,336	0.2823	Moderate
Plastics & rubber products manufacturing	522	0.0141	Low
Non-metallic mineral product manufacturing	14,225	0.7094	Low
Primary metal manufacturing	23,903	0.3687	Low
Fabricated metal product manufacturing	172	<0.01	Low
Machinery manufacturing	<10	<0.01	Moderate
Computer & electronic product manufacturing	43	<0.01	Low
Electrical equipment, appliance & component manufacturing	<10	<0.01	Moderate
Transportation equipment manufacturing	609	<0.01	High
Furniture & related product manufacturing	11	<0.01	Low
Miscellaneous manufacturing	26	<0.01	Low

* Emissions by industry were obtained from Canada's 2021 National Pollutant Release Inventory.

** Industry outputs were obtained from Canada's 2021 Annual Survey of Manufacturing and Logging Industries.

*** Product emissions were estimated based on Canada's 2021 Greenhouse Gas Inventory in-which:

- Products with emissions exceeding 100 Mt CO₂ equivalent are categorized as "High",
- Products with emissions below 100 Mt CO₂ equivalent, but exceeding 1 Mt CO₂ equivalent are categorized as "Moderate",
- Products with no emissions, or emissions below 1 Mt CO₂ equivalent are categorized as "Low".



A thorough review of studies, reports and databases on decarbonization and its implications on individual products and processes in manufacturing was conducted to identify the manufacturing sub-industries in which products, processes, and activities directly or indirectly contribute to significant carbon emissions, making them potential targets for decarbonization efforts. These decarbonization efforts will carry various implications for manufacturing industries and sub-industries. Manufacturing operations or products may undergo changes or technological upgrades aimed at reducing emissions, which, in turn, may have implications on businesses and their workforce. In certain cases, products or processes within these sub-industries may be phased out altogether, leading to business closures and potential job losses. As a result of this, these manufacturing sub-industries may be potentially challenged in decarbonizing their operations and reducing their carbon footprint.

This analysis presents a useful framework for understanding the potential implications and challenges associated with transitioning to a low-carbon economy within the

manufacturing sector. It also assists in identifying which industries and products will require the most attention, investment, and intervention throughout this transition. Coupled with data on employment and businesses in the manufacturing sector, the analysis provides an additional layer of detail on the potential implications and challenges of decarbonization measures on manufacturing companies and their workers.

Following a thorough review of the 248 manufacturing sub-industries, as well as their products, processes and activities, our analysis identifies 41 sub-industries which may be potentially challenged in transitioning to a decarbonized economy. Table 2 demonstrates the number of sub-industries in each industry, as well as the number of sub-industries identified as potentially impacted and challenged in decarbonizing within each industry. Table 3 further details the list of 41 manufacturing sub-industries along with number of employees and business within each sub-industry. Overall, the 41 manufacturing sub-industries employ a total of 285,125 workers in more than 4,800 businesses.



Table 2. Number of potentially challenged sub-industries within each manufacturing industry, along with the number of employees and businesses within each industry

Industry	Number of Sub-Industries within Industry	Number of Sub-Industries Identified as Potentially Challenged in Decarbonizing	Number of Employees	Number of Businesses
Food Manufacturing	34	-	267,754	6,387
Beverage & tobacco product manufacturing	7	-	49,063	1,876
Textile mills	7	-	5,877	263
Textile product mills	4	-	9,080	605
Clothing manufacturing	4	-	18,246	1,187
Leather & allied product manufacturing	3	-	2,872	160
Wood product manufacturing	14	-	98,822	3,218
Paper manufacturing	12	-	47,681	532
Printing & related support activities	6	-	41,900	3,169
Petroleum & coal product manufacturing	4	2	14,185	377
Chemical manufacturing	20	4	89,031	2,127
Plastics & rubber products manufacturing	15	1	112,521	2,036
Non-metallic mineral product manufacturing	12	8	52,088	2,155
Primary metal manufacturing	13	5	52,339	548
Fabricated metal product manufacturing	21	2	178,730	7,627
Machinery manufacturing	17	6	148,084	4,576
Computer & electronic product manufacturing	9	-	53,756	1,541
Electrical equipment, appliance & component manufacturing	11	2	36,439	1,106
Transportation equipment manufacturing	18	11	183,341	1,965
Furniture & related product manufacturing	10	-	77,212	3,863
Miscellaneous manufacturing	7	-	65,547	5,278



Table 3a. List of manufacturing sub-industries potentially challenged in decarbonizing, along with the number of employees and businesses within each

Sub-Industry	Number of Employees	Number of Businesses
Petroleum refineries	7,596	34
Other petroleum and coal product manufacturing	2,068	58
Petrochemical manufacturing	1,864	20
Chemical fertilizer manufacturing	1,366*	57
Mixed fertilizer manufacturing	3,882*	162
Pesticide & other agricultural chemical manufacturing	755	22
Tire manufacturing	4,554	58
Glass manufacturing	2,292*	81
Glass product manufacturing from purchased glass	6,028*	213
Cement Manufacturing	2,523	40
Ready-mix concrete manufacturing	13,647	748
Concrete pipe, brick and block manufacturing	4,012	126
Other concrete product manufacturing	7,865	295
Lime manufacturing	691	16
Gypsum product manufacturing	2,740	36
Iron & steel mills & ferro-alloy manufacturing	13,795	63
Primary production of alumina & aluminum	2,832	20
Non-ferrous metal smelting & refining	8,454	28
Iron foundries	2,157*	45
Steel foundries	1,438*	30
Forging	1,675*	72
Metal tank (heavy gauge) manufacturing	4,704	138
Construction machinery manufacturing	7,582	222
Mining & oil & gas field machinery manufacturing	10,685	338
Heating equipment & commercial refrigeration equipment manufacturing	15,467*	301
Turbine and turbine generator set unit manufacturing	897*	26
Other engine & power transmission equipment manufacturing	3,140*	91
Pump and compressor manufacturing	5,190	118
Motor and generator manufacturing	2,366*	60
Battery manufacturing	780	36
Light-duty motor vehicle manufacturing	24,834	25
Heavy-duty truck manufacturing	4,225	27

* Employment estimate



Table 3b. Continued - list of manufacturing sub-industries potentially challenged in decarbonizing, along with the number of employees and businesses within each

Sub-Industry	Number of Employees	Number of Businesses
Vehicle gasoline engine & engine parts manufacturing	6,042	81
Vehicle electrical & electronic equipment manufacturing	5,068	92
Motor vehicle transmission and power train parts manufacturing	11,067	78
Motor vehicle metal stamping	17,009	103
Other motor vehicle parts manufacturing	14,722	231
Aerospace product & parts manufacturing	39,239	295
Railroad rolling stock manufacturing	6,687	36
Ship building & repairing	4,850	132
Other transportation equipment manufacturing	8,337	185

It is worth noting that not all manufacturing industries and sub-industries face the same challenges in this transition. Some manufacturing industries and sub-industries may encounter unique obstacles and complexities when it comes to decarbonization. Factors such as the nature of the product, the production processes, reliance on specific raw materials, or the availability of alternative technologies can influence the degree of challenge they face. Some industries and sub-industries may be also presented with new opportunities to diversify their product offerings and play a role in the clean energy transition. Other sub-industries may be adversely affected, and companies within these sub-industries may face the risk of going out of business. Without substantial innovation or transformative changes, these sub-industries may find themselves unable to compete in a decarbonized market.

For instance, industries that heavily rely on fossil fuels as their primary energy source or those that produce goods with a significant carbon footprint may face immense challenges. The petroleum refineries, and petroleum and coal product manufacturing businesses are among the most impacted by the phasing out of fossil fuels products and will be highly challenged in decarbonizing without fundamentally changing their activities and line of products. In Canada, more than 9,600 workers are employed in 92 petroleum refinery, and petroleum and coal product manufacturing businesses. Most businesses within these sub-industries will be highly susceptible to loss in revenue or closure due to a decline in the demand for traditional fossil fuel products, and the rise in use of alternative energy sources. Employment within the two sub-industries is expected to decline as a result of business closures, or the transition of businesses to alternative markets.



Similar implications are expected in the mining and oil and gas field machinery manufacturing sub-industry where more than 10,500 workers are employed in 338 businesses. As the demand for fossil fuel products declines, so does the demand for the heavy machinery used in oil and gas extraction and processing. Businesses and workers involved in oil and gas field machinery manufacturing are expected to be challenged in decarbonizing, however an opportunity is presented with the transition to clean energy technologies. Businesses may transition to cater to the growing demand for minerals and materials required for clean energy technologies.

Disruptions and challenges are also anticipated within the automotive manufacturing industry, and more specifically the vehicle gasoline engine and engine parts manufacturing sub-industry, which employs more than 6,000 workers across Canada. The rise of EVs could potentially disrupt the gasoline engine manufacturing sub-industry, leading to a decline in demand for ICEV engine components and parts. Businesses and workers in this sub-industry are potentially at high risk and are highly challenged in this transition.

Other industries and sub-industries are technologically and logistically challenged in transitioning to a decarbonized economy. For example, within the plastics & rubber products manufacturing industry, we identify tire manufacturing as potentially challenged in decarbonizing. Tires have a high carbon footprint which is a result of the high carbon emissions during tire production, the production of their raw materials, as well as during their use. While the industry has made progress in exploring alternative materials

and greener manufacturing practices, scalability in tire production, and the complexity of tire performance requirements present ongoing challenges in the decarbonization of tire manufacturing.

Similarly, cement production emits high levels of CO₂ during production however, the industry has limited alternatives for raw materials, feedstock or energy sources. While the industry is exploring new production technologies and material alternatives, these solutions may not be economically feasible or scalable for years, and could require significant investment in research, infrastructure and new manufacturing processes. However, a subsequent transition away from the traditional methods and raw materials of cement may carry implications beyond the cement production sub-industry to neighbouring sub-industries such as concrete and lime manufacturing.

Industries and sub-industries may also have to make significant investment and changes to implement readily-available technologies and practices that assist them in decarbonizing their operations. For example, the iron and steel manufacturing sub-industries are expected to be challenged in decarbonizing as they are highly energy-intensive, and generate significant GHG emissions during production. This includes sub-industries such as iron and steel mills and ferro-alloy manufacturing, metal smelting and refining, iron and steel foundries, and the forging sub-industry. Collectively, these sub-industries employ 30,350 workers in more than 250 businesses across Canada. The iron and steel manufacturing industry has been making progress towards decarbonization through implementing readily available energy-efficient production technologies such as



electric arc furnaces and hydrogen-based steelmaking, as well as using scrap metal as alternative feedstock. These changes will require some level of investment, and will introduce some changes to activities and operations. Workers' upskilling may be required to operate the newly-introduced technologies.

Finally, some industries and sub-industries are presented with the opportunity to diversify their product offerings and play a key role in the clean energy transition. However, they are also potentially challenged to significantly ramp up their output and innovate in the coming years. For example, the battery manufacturing sub-industry is expected to experience growth as the demand for EVs and energy storage systems increases. Similarly, the vehicle electrical and electronic equipment manufacturing sub-industry is set to play a pivotal role in supporting the manufacturing of EVs, and the supply of the higher content of electrical and electronic components in these vehicles. Nonetheless, both these sub-industries face the challenge of scaling up their production capabilities and innovating to meet the growing market needs of the decarbonized economy.

Using the analysis presented above, it is possible to identify the number of workers and businesses which are potentially challenged as a result of a full rollout of decarbonization measures and policies. It is also possible to identify the sub-industries that may require more support, investment and attention in the transitioning to a low-carbon products and processes. Workers in some sub-industries may require upskilling and training to accommodate any changes in the required skills which may be accompanied with the implementation of the new technologies.

In 2021, Canada's manufacturing sector employed around 1,605,000 workers in more than 50,000 businesses. Our analysis finds that the majority of the manufacturing workers (approx. 1,300,000 workers) and businesses (approx. 44,000 companies) remain unchallenged by decarbonization measures.

However, attention should be directed towards companies and workers within industries and sub-industries which are potentially challenged by the transition, as these may require support, investment and intervention to ensure a successful and smooth transition to a low-carbon economy. This includes sub-industries that are potentially highly impacted by decarbonization measures, including the sub-industries of petroleum refineries, mining and oil and gas field machinery manufacturing, and motor vehicle gasoline engine and engine parts manufacturing. Without targeted support, these sub-industries and their workers may be at high risk if businesses are unsuccessful in making fundamental changes to the products or processes. In such cases, policymakers should intervene and ensure that workers are transitioned to other low-carbon industries to minimize the impact on the overall sector and economy. Another area of focus should be the businesses that are expected to allocate significant capital to invest in the adoption of readily-available technologies and train their workers to keep up with the newly introduced technologies in the workplace. Policymakers should provide the necessary support to assist businesses and workers in these challenged sub-industries in successfully navigating the transition to a low-carbon economy.



Concluding Remarks

The information offered in our analysis is a starting point for policymakers and stakeholders in their efforts to design effective policies and programs that ensure a successful and smooth transition to a low-carbon economy, while minimizing job losses and economic disruptions. The analysis shows that while the number of workers and businesses challenged by decarbonization measures is relatively small compared to the total number of workers and businesses in the manufacturing sector, however, in absolute terms, the number remains substantial. It is also important to note that while some sub-industries and workers will

be facing significant challenges in adapting to the new measures, other parts of the manufacturing sector will be growing as they capitalize on new opportunities and technologies. Moreover, in a low-carbon economy, the manufacturing labour force should be equipped with the necessary skills, and should receive the appropriate training to adapt to changing job requirements in the manufacturing sector. This can be achieved through targeted education and training programs, and collaboration between businesses, policymakers, educators, and other stakeholders.



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